



## Proceedings of the CIB World Building Congress 2016

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Proceedings of the CIB World Building Congress 2016

*Volume I*

# Creating built environments of new opportunities

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TAMPERE UNIVERSITY OF TECHNOLOGY





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Kalle Kähkönen & Marko Keinänen (eds.)

# WBC16 Proceedings : Volume I

## Creating Built Environments of New Opportunities



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# Preface

## 1. CIB World Building Congress 2016

CIB World Building Congresses (WBCs) are triennially arranged major research events for the built environment and construction sector. In 2016 this congress is organized in Finland ([www.wbc16.com](http://www.wbc16.com)). This event is gathering together academic experts together with industry representatives from different parts of the world. The theme for CIB World Building Congress 2016 is "Intelligent built environment for life". It highlights the importance of build environment and its development to the society.

The WBC16 congress is a major event for all experts from industry, public sector and academia for advancing the development of built environments. The main theme of the WBC16 "Intelligent built environment for life" presents a cogent message that the built environment is a very important enabler for the well-being of its citizens, the success of its companies and the competitiveness of whole society, region or country. By defining the role of built environments in this way we can see the fundamental importance of our real estate and construction sector. In the WBC16 congress we turn our attention to the development of built environments in different conditions, countries and continents. Such developments can happen in different forms and scales, but always in a way where interplay between different stakeholders and experts play crucial role. These developments also need access to the latest knowledge and understanding which can be based both on industrial experiences and research-based findings.

Together, and by learning from each other we can be stronger and smarter for carrying out efforts where the main target is to deliver solutions that can be called Intelligent built environments for life. Our global umbrella organization CIB has three priority themes which are seen as focus areas for overall development and transformation of real estate and construction sector. These themes are Sustainable Construction, Integrated Design and Delivery, and, Resilient Urbanisation. The CIB priority themes present the overall framework for the content of this congress, supported and underpinned by specific congress sub-themes. In the WBC16 event a holistic viewpoint over this topic is presented that includes different dimensions from built environment as a system down to pragmatic end-user experiences and daily operations.

Seven sub-themes were developed to showcase the main areas where the majority of contributions was expected in the forms of presentations, workshops, special sessions and relating papers. Each sub-theme is presented using a simple but general challenge that expresses direction or need for different contributions. Each of these areas represents a broad totality. Thus, anyone whose work and expertise relates to the built environments can clearly place their work in one of these seven areas easily. The activities of CIB constitute work by a wide variety of different Working Commissions and Task Groups. The contributions from these bodies are linked to these sub-themes (Figure).

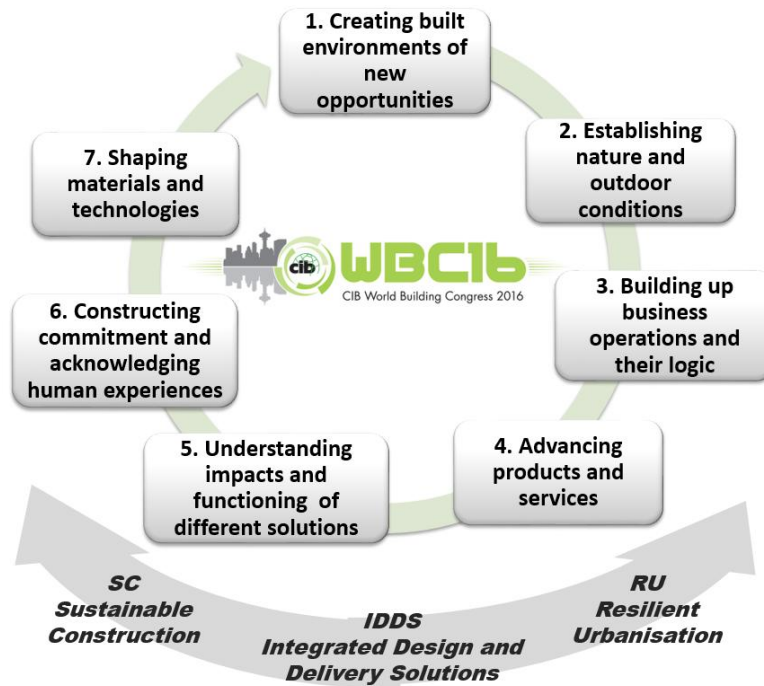


Figure. The sub-themes of the World Building Congress 2016.

## 2. Introduction to the WBC16 proceedings

The WBC16 call for papers produced 550 paper proposals. All abstracts and full paper submissions were double blind reviewed by the members of WBC16 International Scientific Programme Committee. Finally, 360 paper contributions were accepted to be published in the WBC16 proceedings. We would like to take this opportunity to express our sincere appreciation to the WBC16 International Scientific Programme Committee and all editors of the WBC16 proceedings. All members of this committee can be found in the chapter four of this preface.

The WBC16 proceedings comprise five pdf-books (Volume I-V). The contents of different books are according to the sub-themes of WBC16 as presented on the following.

Volume		Editors
I	<ul style="list-style-type: none"> <li>Creating built environments of new opportunities</li> </ul>	Kalle Kähkönen <a href="mailto:kalle.e.kahkonen@tut.fi">kalle.e.kahkonen@tut.fi</a> Marko Keinänen <a href="mailto:marko.keinanen@tut.fi">marko.keinanen@tut.fi</a>
II	<ul style="list-style-type: none"> <li>Establishing nature and outdoor conditions</li> <li>Constructing commitment and acknowledging human experiences</li> </ul>	Matthijs Prins <a href="mailto:M.Prins@tudelft.nl">M.Prins@tudelft.nl</a> Hans Wamelink <a href="mailto:J.W.F.Wamelink@tudelft.nl">J.W.F.Wamelink@tudelft.nl</a> Bob Giddings

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IV	<ul style="list-style-type: none"> <li>Understanding impacts and functioning of different solutions</li> </ul>	Suvi Nenonen <a href="mailto:suvi.nenonen@tut.fi">suvi.nenonen@tut.fi</a> Juha-Matti Junnonen <a href="mailto:juha-matti.junnonen@tut.fi">juha-matti.junnonen@tut.fi</a>
V	<ul style="list-style-type: none"> <li>Advancing products and services</li> </ul>	Nebil Achour <a href="mailto:Nebil.Achour@anglia.ac.uk">Nebil.Achour@anglia.ac.uk</a>

### 3. Introduction to the Volume I of WBC16 Proceedings

Volume I includes 75 paper contributions linked to the congress sub-theme “Creating built environments of new opportunities”. This includes topics of three different levels. First the macro-level contributions cover aspects such as development policies and programmes on national or international levels for creating desirable systemic changes (sections: I, II). Second the meso-level aspects mean here certain topics relating to e.g. organizations and their operations, implementations or performance of new solutions or systems such as complete buildings (sections: III-VII). Third the micro-level topics are addressing particular contexts and their solutions, such as a specific building code, structure, material and analyses relating those (sections: VI-IX). The paper contributions included in Volume I are classified into the following nine book sections.

- I: Policies and programs for the development of built environment (11 papers)
- II: Lessons learned from regional challenges (9 papers)
- III: Meeting successfully different stakeholders and their interests (11 papers)
- IV: Towards advanced solutions for sustainability and resilience (10 papers)
- V: Reshaping processes for construction operations (9 papers)
- VI: Successful implementation of BIM technologies for the realisation of potential benefits (7 papers)
- VII: Innovative buildings and their performance (8 papers)
- VIII: Building regulations and control in the face of climate change (6 papers)
- IX: Moisture and mould Issues (4 papers)

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# Radical Programmes for Developing the EU Residential Building Sector

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## Abstract

The economic recession has hit especially hard the residential building sector in the EU region, e.g., the number of the housing completions has decreased -49% and the total residential output has been squeezed down by -24% between 2007 and 2014 (Euroconstruct, 2015). In turn, the aim of our paper is to suggest a set of radical, novel programmes for developing the national residential building sectors within EU member countries up to 2025. We have applied the framework of strategic niche management (SNM) to the diagnoses of the current portfolios of the innovation, R&D programs in our two member country contexts. In the case of the Northern Finland, the prime example is Hiukkavaara, the largest district to be built in the City of Oulu. Homes will be constructed for 20,000 new residents. Hiukkavaara is a model for climate-conscious design in the northern hemisphere. Energy and materials are conserved, nature is valued and human beings adapt to their environment. One sub-programme involves Future Buildings and Renewable Energy Project. In the case of the Netherlands, the prime example is Energiesprong (Energy Leap), i.e., the innovation programme commissioned by the Dutch Ministry of the Interior. The aim is to make buildings energy-neutral and boost large-scale initiatives. The sub-programmes are targeting homes owned by housing associations, privately owned homes, office buildings, shops and care institutions. This programme is about ensuring new supply by encouraging companies to package a variety of technical sub-solutions, full services and financing options as well as about asking clients to put out tenders and ask for quotes in novel ways, with the government making changes to the rules and the regulations. Experiences on which the Dutch case in this paper focuses are sub-programmes for residential buildings which includes Rapids, All Lights on Green and Our Home Deserves It. Based on the emerging Finnish and Dutch evidence, we are suggesting key elements to be incorporated into future national residential programmes within EU member countries on: (1) radical direction with balanced stakeholder groups, trustworthy advocates, contextual goal-setting and barriers management, (2) radical networking with entrepreneurial roles and causal links, novel expertise, transparent choices and digital platforms and (3) radical learning processes to arrive at better informed markets on user preferences, co-innovating, new rules and regulations, higher performance/price ratios, higher quality, new roles and responsibilities assignments.

**Keywords:** Hiukkavaara, Energiesprong, innovation programme, residential building sector

# 1. Introduction

The economic recession within the EU member countries has had its negative consequences vis-à-vis the real estate and construction sector. Especially, the residential building sector has been hit hard, e.g., the number of the housing completions has decreased -49% and the total residential output has been squeezed by -24% between 2007 and 2014 (Euroconstruct, 2015). Therefore a new innovation impulse is needed. The aim of our paper is to suggest a set of radical, novel programmes for developing the national residential building sectors within the EU.

The concept 'system of innovation' is widely accepted as a unit for studying innovations. Its operating level varies. For industries like construction, the national level is the most appropriate level (Lundvall, 1999). Research is not the only source of industrial innovation, i.e., other sources include knowledge flows, co-operation and technology diffusion (OECD, 1998). Moreover, common culture, legal framework, education, customer preference, institutions and other variables impact innovation. For industries like construction the latter may be more significant than research. Manseau and Saeden (2001) have shown that some countries have established technology and best-practice diffusion networks in construction.

In turn, the aim of our paper is to suggest a set of radical, innovative programmes for developing the national residential building sectors within EU member countries up to 2025. We have adapted the 3-area framework of strategic niche management (SNM) to diagnose national programmes (Section 2). We have selected a case programme within Finland (Section 3) and another within the Netherlands (Section 4) to exemplify and diagnose some radical solutions and features readily being adopted, such as participative district planning and the co-alignment of wilderness and residents. Finally, we put forth the key suggestions (Section 5).

## 2. Programme diagnosis method and data

### 2.1 Theoretical diagnosis framework

For innovation at the level of (a part of) an industry, generally the term transition is used. Socio-technical transitions have emerged from evolutionary economics (Nelson & Winter, 1977; Dosi, 1982). From the studies of former major societal changes, the insights have emerged about experimentation, multi stakeholder learning, coevolution of technologies, organisational forms, rules, regulations and financial systems. This has resulted in the theories of Strategic Niche Management (SNM) and Multi Level Perspective (MLP) (Geels & Kemp, 2007; Loorbach & Rotmans, 2006) that can be used to evaluate innovations. Innovations start in niches, but their further development is highly dependent on developments at different societal levels. SNM describes the role of emerging innovative niches in becoming mainstream in combined social and technological systems. This innovation management perspective focuses on the formation of niches in which innovations can flourish. SNM describes the transition by reporting on the three processes which enable for a successful technological niche (Kemp et al., 1998):

- The articulation of expectations and visions. Such articulation would provide a direction to the learning process of parties involved and help to attract attention from necessary stakeholders and legitimate involvement and support.
- Construction of social networks. The interaction of stakeholders is needed to collect resources (time, expertise and money) and commitment required.
- Learning on multiple aspects. Such aspects include technical aspects and design specifications, market and user preferences, cultural and symbolic meaning, infrastructure and maintenance networks, industry and production networks, regulations and governmental policies as well as societal and environmental effects.

In turn, MLP uses the following indicators for reviewing the stabilization of niche-innovations that are ready to break through: (a) learning processes have stabilized in a dominant design, (b) powerful actors have joined a network, (c) price/performance relations have been improved and there are strong expectations of further improvement and (d) the innovation is used in niche markets, which amount to a market share of more than 5% (Grin et al., 2010).

For the context of this paper, we have merged the three processes distinguished by Kemp et al. (1998) and the list of the sub-topics with the indicators specified by Grin et al. (2010) into a diagnosis framework containing (1) clear direction, (2) network formation and (3) learning on the six aspects, i.e., (a) market and user preferences, (b) product and process innovations, (c) new rules and regulations, (d) price and performance improvements, (e) architecture, environment and quality improvements as well as (f) roles and responsibilities.

## **2.2 Prior empirical studies enabling the diagnosis**

The diagnosis of the Finnish innovation programme, Hiukkavaara district in the City of Oulu, is based on the review of references published in English and Finnish, available via the website.

The diagnosis of the Dutch innovation programme is in part based on the case study research on the two of the 4 sub-programmes and the annual report of Energy Leap (Energiesprong, 2015). For the study of the Rapids sub-programme different pilot projects were visited in Heerhugowaard (7 April 2015), Nieuw Buinen and Emmen (both on 24 April 2015) and Soesterberg (3 June 2014). More direct information came from the meetings with Energy Leap and Rapids and conversations. The additional information was accessed via the websites of the partners of the programme. The detailed results have been reported via Oostra (2015a-b). In turn, the study of the LALOG sub-programme is based on the experience of Oostra as a member of the board of #ENEXAP between November 2013 and April 2015. Various projects were undertaken to facilitate owner-occupants to make their desires and needs explicit, to analyse the situation in their houses and to gather the information necessary for the inclusion of professionals, the formation of consortia, to provide training to make them fit for the job, etc. Data was gathered via action research, board meetings, occupant meetings, meetings with Energy Leap, study meetings with companies, meetings with other LALOG initiatives and conversations with people involved. The key results have been reported via Oostra (2015b) and Oostra & Been (2016).

### **3. Finnish case programme diagnosis**

#### **3.1 Hiukkavaara District as the case programme**

The City of Oulu boasts to be “the Capital of the Northern Scandinavia”. The prime example is the Hiukkavaara, the largest district to be built. The development started in 2008. Homes for 20,000 new residents will be constructed around the old barracks area. The housing plan includes 10 000 homes, i.e., 3 200 apartments, 3 300 terraced houses, 2 000 semi-detached houses and 1 500 single-family houses (City of Oulu, 2015). 1,800 workplaces are being facilitated. In addition, the nearby Hiukkavaara Centre will serve 40,000 Oulu residents. Hiukkavaara is a model for climate-conscious design in the northern hemisphere. The Head of Urban Developments assures that energy and materials are conserved, nature is valued and human beings will adapt to their environment (City of Oulu, 2015). Best practices for developing construction and zero-energy buildings are being identified, assessed and implemented. The construction started in 2013. The first buildings were ready in Summer 2014. The building physical modeling started in the end of 2014. About 80% of the target area will be under construction by Winter 2015. The piloting culture in the City of Oulu is being continued via this project (Seppälä & Mikkonen, 2015).

#### **3.2 Results of the diagnosis of Hiukkavaara district**

(1) FINNISH CLEAR DIRECTION. The City of Oulu has defined the 14 guidelines for the development of Hiukkavaara District, i.e., to take into account (i) the nature and landscape values, (ii) a densely-built neighbourhood of urban houses in a versatile environment, (iii) dense 7-zone residential areas bordering on large green areas, (iv) comprehensive services, (v) cycling, walking and public transportation, (vi) facilities and areas for sports, recreation and outdoor activities, (vii) an integrated storm water system, (viii) alternatives and impact assessments, (ix) participatory planning, (x) cost efficiency, (xi) development projects on Living Lab platform, (xii) energy efficiency, (xiii) city farming and (xiv) art in urban space (Kallioniemi, 2012). During 2008-2015, a series of the pilot projects have concerned calculating life-span efficiency in city building (KERVO; Vainio et al., 2012), integrating urban development concept, partnering for an arctic, smart and sustainable city (INURDECO), consulting builders in choosing concepts for renewable energy efficiency solutions (RESCA), innovating public procurement with life-span and R&D, arranging the Living Lab and services, researching winter city, stimulating the creative sector in the former military barracks area, engineering ICT solutions for traffic, safety and lighting, designing home information systems, and piloting Smart City ICT platform and service center, RadioCity 2020 (Kallioniemi, 2012).

In turn, the goal of the Future Buildings and Renewable Energy Sub-Project is to create common operating models to builders and to exchange and implement the best renewable energy and energy efficiency practices generated during the pilot project. The sub-goals of the joint project are (i) to intensify the development of renewable energy technologies, (ii) to promote the spreading of successful solutions to other cities throughout Finland and (iii) to develop them into business models (Seppälä & Mikkonen, 2015).

(2) FINNISH NETWORK FORMATION. Companies and educational institutions co-develop products and jointly execute research. User experience and information about the operability of new solutions is being collected via Living Lab. A 3-circle network is being established. The inner circle involves the 12 pilot site builders and each of them is collaborating with design offices, material suppliers, etc. The builders have been selected based on their proposals to meet one of the three energy efficiency levels. In Group 1, each project including nearly zero energy solution or E-Number < 35 can freely choose a lot. In Group 2, each project where heat loss and E-Number are at maximum 60% of the minimum level defined in the norms can select the best possible lot after Group 1. In Group 3, each project where heat loss and E-Number are equal or less than 70% of the minimum level defined in the norms can get a lot, if it is not selected earlier. The middle circle consists of Building control of the City of Oulu and Business Oulu's seminars/educational events having around 80 enterprises and nearly 1000 participants. The broader circle with the E-mail list has over 250 contacts (Seppälä & Mikkonen, 2015).

(3a) FINNISH LEARNING ON MARKET AND USER PREFERENCES. City of Oulu is developing its user-oriented Hiukkavaara as follows. It listens to its residents and companies, has conversations with them and serves them. This "low-threshold" city gives its residents space to express themselves and creates opportunities to exercise recreational activities and enjoy the nature. Apartments, buildings, blocks, yards, streets and parks are all designed for human-scale life. Residents can walk, cycle and ski. Nature starts at the front door, yet shops and cultural events are within walking distance. Dwellings are accommodating specific client groups: young, middle-aged and older residents. Future residents can choose their own ways of life. Urban gardening allows for home-grown vegetables and herbs. Services include schools, day-care centres, youth centres, a residential community centre, health services, commercial services, a swimming pool, an ice stadium, a sports hall, sports fields, a fitness centre, Aalikkokangas Sports Centre and 250 kilometers of cross-country ski tracks. Old Hiukkavaara is a meeting point for actions and ideas. The culture life has discovered the renovated old barracks. Crazy ideas have resulted in successful companies. Work, activities and new business ideas are based on creative energy. Hiukkavaara is already one of the biggest centres of the creative sector in the Northern Finland. There are some 250 rehearsing bands. Artists, photographers, graphic designers and sheet-metal workers are merging with the new growth platforms. All this is being blended with the ICT expertise of the city (City of Oulu, 2015). Officials and experts are giving occupants advice on the usage and maintenance of buildings (Seppälä & Mikkonen, 2015).

(3b) FINNISH LEARNING ON PRODUCT AND PROCESS INNOVATIONS. Hiukkavaara district offers premises for R&D, testing and launching to tackle critical issues like "How can a home become energy efficient?", "How are renewable energy sources utilised?" and "What kind of new services are needed in the future?" Companies developing services can get inspiration by observing the behaviour of locals. The performance of energy production and consumption, building automation systems and building physics are being measured and analysed. The challenges are related to the levels of energy design, moisture management as well as automation and control systems. For example, Saikotek Oy has installed the building-physical measurements in its pilot building. University of Oulu is modelling the building-physical operation of structures by utilising data from these measurements. In Sonell Oy's building, heat is produced by a ground-

source heat pump and distributed to room air by a radiant floor heating system. About 30 m<sup>2</sup> of the solar collectors are on the roof of a shared technical room. A home automation system is controlling heating, ventilation and safety systems (Seppälä & Mikkonen, 2015). Besides, Hiukkavaara has an international digital service home where ICT companies take part in developing services to support living and recreational activities. Living Lab is packed with the development themes of a sustainable city, i.e., energy efficient dwellings, intelligent electric networks, block models of a winter city, alternative and regenerative forms of energy, ecological water system, centralised waste management, functional public transportation, safe wintertime cycling and related ICT services (City of Oulu, 2015).

(3c) FINNISH LEARNING ON NEW RULES AND REGULATIONS. Subarctic and arctic areas like Hiukkavaara district require special technologies and skills to build climate friendly, energy efficient and user oriented winter cities with innovative services and logistics processes. For example, the Ecocity Evaluator software is used to assess the energy consumption of the community development, the carbon dioxide emissions and the costs based on the master and city plans. The software enables the assessment of the emissions of both production and consumption. The assessment takes into account buildings, traffic, energy production, industry, agriculture and carbon sinks. Comparisons with other Nordic cities are also being relied upon (Kallioniemi, 2012).

(3d) FINNISH LEARNING ON PRICE AND PERFORMANCE IMPROVEMENTS. The initial present value of the life-cycle costs for Hiukkavaara district as a whole is about EUR 3,4 billion. Thereof, the majority share of the residential buildings is EUR 3,0 billion (87%), the share of the community services is EUR 165 million (5%) and the share of the infrastructures is EUR 280 million (8%). Both the present value method and the annuity method have been relied upon. The calculations are based on the 50-year life-cycle and the 3% interest rate. All the costs are reported as those of the first quarter of the year 2012 without VAT. Concerning each of the three sectors, the five sub-cost categories include lot prices, construction, maintenance, operations and demolition. When the district plan accommodates 20 000 residents, the average life-cycle costs per resident is about 170 000 euros (Vainio et al., 2012).

(3e) FINNISH LEARNING ON ARCHITECTURE, ENVIRONMENT AND QUALITY IMPROVEMENTS. Hiukkavaara acts as the centre of city life in all four seasons, also as a big recreational area. The land area is 1,500 hectares. The architecture of a snowy city, the sunshine of a crisp winter day and the joys of winter time sports provide new opportunities for district design. For example, the same designated areas are used in the winter for storing snow and in the summer for playing floorball and basketball. Different routings are provided: if weather is good, people can enjoy fresh air, but if it is bad, they can choose a covered route protecting from rain. Streets and parks create opportunities for walking a dog or doing some parkour. Special attention is being paid to make nature and wilderness an integral part of the design, connecting nearby beaches along riverbanks and lakeside, heathlands, boulder fields and marshes with paths and duckboards. Arctic wilderness involves forest animals, snowmobiles and hounds. Ideally, “recreational areas are within walking or cross-country skiing distance. Seasonally changing light and nature are part of city life. The district is designed to be the model city for sustainable

community planning. Houses, streets, districts and landscapes create a rich and diverse cityscape. Houses come in different shapes and sizes, even on top of each other. Various lifestyles are visible in its architecture. Urban gardening is visible in gardens and on rooftops.” (City of Oulu, 2015).

(3f) FINNISH LEARNING ON ROLES AND RESPONSIBILITIES. The adoption of the viewpoint of sustainable development in construction creates new and expands existing business opportunities during all phases within building processes. In addition to life-cycle projects suitable for large companies with risk-bearing capacity or novel networks, sustainable construction offers opportunities also for small, local companies. In the design of one- and two-family house dominated residential areas, value chains from general design to finished residential areas take many years. Designers and contractors alike are being advised to retain possibilities to make future changes instead of meeting exact needs among particular clients. Value chains are developing solutions for changing operating environments and uses of buildings (Vainio et al., 2012).

## **4. Dutch case programme diagnosis**

### **4.1 Energy Leap as the case programme**

The Dutch innovation programme described herein is Energy Leap (Energiesprong, 2015), commissioned by the Dutch Ministry of the Interior. The extended programme ran between 2010 and 2015. The aim was to make buildings energy-neutral and boost large-scale initiatives targeting dwellings, office buildings, shops and care institutions. The four most ambitious sub-programmes targeted at dwellings, i.e., (i) All Lights on Green (LALOG Lokaal Alle Lichten Op Groen) with owner-occupants was seeking to make homes energy-neutral, (ii) Rapids Rental (Stroomversnelling huur) was set to renovate rental houses to the level of nearly zero energy buildings and to overcome the financial problems and the restricted resources that the housing associations were dealing with, (iii) Rapids Purchase (Stroomversnelling koop) focused on the market for owner-occupants and (iv) Our Home Deserves It (Ons huis verdient het) campaign was launched to show to banks and companies that owner-occupants are interested in converting their homes to net zero homes and the TV show highlighted the results of Rapids Purchase. When the national funding of Energy Leap came to an end in December 2015, the arrangements have been put in place to continue the funding via the partners already involved. In many regions, e.g., Utrecht, Brabant and Overijssel/Gelderland, plans have been made to set up regional agreements with dedicated (new) partners to retrofit substantial amounts of dwellings.

### **4.2 Results of the diagnosis of the four sub-programmes and the pilot projects**

(1) DUTCH CLEAR DIRECTION. LALOG provided support to the groups of owners in Apeldoorn, Wageningen, Den Bosch, Hoorn, Amsterdam and Amersfoort. The objective was to bring at least 20 homes in each municipality to energy-neutral via the process of learning by doing by residents, builders, municipal officers, contractors, brokers, appraisers and bankers. In turn, the goal of Rapids Rental was set to deeply retrofit and convert the 111.000 rental houses owned



by the associations before 2020 to the level of zero-to-the-meter (on a yearly basis), block by block, within two weeks, for 45k/dwelling and satisfied occupants. This clear goal has become the joint ambition of an entire network. Rapids Rental was considered to be the best example by the Building Performance Institute Europe (Staniaszek, 2014). Rapids Purchase was aiming at similar goals for individual privately owned dwellings.

(2) DUTCH NETWORK FORMATION. Considerable efforts have been made in the building of all sorts of networks to come up with technical and social innovations that are needed for large scale retrofitting of dwellings without additional subsidies. This provided a solid base to further integrate necessary solutions and make operations more cost efficient. At the beginning, ad hoc coalitions were created for zero-to-the-meter retrofitting, project-by-project, in design competitions. The next step was to create coalitions in municipalities, in which demand would be clustered for local builders (LALOG). However, it turned out the incentive for proper innovation was still not enough. Next step in Rapids Rental was to make deals including the supply chains and housing associations for a series of projects and, thus, fostering a situation in which innovations could emerge across projects. Supporting parties like e.g. brokers, municipalities and financial experts have also been linked to the network. This finally got the innovation process going.

(3a) DUTCH LEARNING ON MARKET AND USER PREFERENCES. The Energy Leap programme provided the opportunity to cluster the preferences of housing associations, tenants and private house owners in different municipalities and contexts. The people executing the Energy Leap programme took the time and effort to reflect on this in several settings. This made it possible for them to draw conclusions on what was necessary to develop a highly industrialized approach for the retrofitting of mass-produced housing from the fifties, sixties and seventies. Also attention was given to the preferences of tenants in order to develop approaches to win them over.

(3b) DUTCH LEARNING ON PRODUCT AND PROCESS INNOVATIONS. In Rapids Rental, the idea was that retrofitting methods can be improved and gradually scaled up to industrial production levels by employing integrated prefabricated building components and deals that included the perspective on a series of projects, to convince the construction sector to make the necessary investments. Process changes were also needed to speed up execution, as well as to improve quality and customer satisfaction. (see for more information: Oostra, 2015b) Originally, the knowledge and the experiences gained by each team related to a specific retrofit project, supply chain or client. In Rapids valuable insights were disseminated via planned sessions with all programme participants and focused meetings with e.g. the housing associations only. The contractors, i.e., Volker Wessels, Dura Vermeer, Ballast Nedam and BAM developed and integrated technical solutions and social innovations to meet the high ambitions set for tenant satisfaction, price levels and house performance levels. Now a new, rather large market is opening up for zero-on-the-meter retrofitting, interactions are set up with the big building product suppliers like BASF and Mitsubishi to realise new products for this market and thereby making concepts even more cost effective and of higher quality (e.g., Gent and Lippens, 2015). Major innovative steps have been made including: new facade components & service components as an integral part of new specific retrofit concepts and the use of BIM, lean and 3D scanning to speed

up the preparation and execution processes. All this is fundamentally different from traditional contracting where the room left for project-specific innovations and risk taking is rather restricted.

(3c) DUTCH LEARNING ON NEW RULES AND REGULATIONS. During Rapids Rental, many adjustments to legislation and regulations were deemed necessary. It turned out crucial to make it legal for social housing associations to use the money tenants pay for energy as a source to fund the retrofit. The problem was that for many houses the rent would go up over the allowance-limit for many houses, if the rent would also include the envisioned energy performance fee. Amendments were also needed in the areas of licensing, energy labelling and exemptions. Exemptions were deemed necessary since related procedures often take half a year. Such delays are costly for stakeholders. Environmental assessments can be speeded up because all the Rapids retrofitting concepts are obliged to meet the requirements set out in the rules for zoning, the Building Act and the Flora and Fauna Act.

(3d) DUTCH LEARNING ON PRICE AND PERFORMANCE IMPROVEMENTS. The first three retrofitting projects of Energy Leap were commissioned in the form of a competition. In the De Kroeven project in Roosendaal in 2010, 244 family homes were renovated by the designs of the two architectural firms, at just over 130,000 euros per home. This reduced energy consumption for heating from 200-150 kWh/m<sup>2</sup> to 30-20 kWh/m<sup>2</sup>. In Kerkrade, 153 homes were renovated in 10 days each at an average of 100,000 euros per home. The homes were fitted with the new façades and roofing, solar panels, high-efficiency combi boilers and mechanical heat recovery ventilation. Monthly, this saved 101 euros, but the tenants saw their charges reduced by just 37 euros a month because of a 64 euro rent increase. In Apeldoorn in 2013, 188 homes should have been renovated in Het Schilderskwartier dating from 1951, at an average cost of 80,000 euros. However, none of the consortia met the financial requirements. In the end, only one plan could match the housing association's requirements by providing for the establishment of an energy company called Energy BV. Since the residents did no longer have a say in the matter, their resistance grew and only 60% of the residents approved the plans, well short of the 70% required by law. This is why the plan for this third project has not been executed. Instead, the housing association opted for a regular B label renovation and continued the energy-neutral experiment on a smaller scale (Oostra, 2013). With the more systemic innovation started with Rapids Rental, the costs of a zero-to-the-meter retrofit for standard row houses dropped to 60k. Plans are in place with the housing associations involved to retrofit a substantial part of their portfolio. Although only about 500 dwellings have been retrofitted by 2015 (van de Groep, 2015), the plan is still to retrofit in total 110 000 houses before 2020. In order to attain such high numbers, it is necessary that the government approves the new regulations concerning the energy performance fee. During the 4-year programme, a considerable improvement of quality (architectural concepts, integrated technical solutions and performance) has been realised in combination with a price drop of more than 50% (Oostra 2015b).

(3e) DUTCH LEARNING ON ARCHITECTURE, ENVIRONMENT AND QUALITY IMPROVEMENTS. An important requirement for housing associations is that these concepts improve the architectural quality of the existing dwellings. Dutch housing associations have noticeably attention to maintain or rather improve the architectural qualities of both the dwellings,

as well as the neighbourhood in which these dwellings are located. In New Buinen e.g., the neighbourhood as a whole will be restructured, by swapping public and private side of the houses and by re-introducing a canal, a typical landscape element for these peat areas. Quality improvement was an aim, but of course there were also teething problems in projects part of Rapids. In Heerhugowaard for example, delamination occurred of the facade finishing (Oostra, 2012b).

(3f) **DUTCH LEARNING ON ROLES AND RESPONSIBILITIES.** The Energy Leap programme has proved that real progress can be made within four years towards a cost-effective, quick, up-scalable and occupant friendly retrofitting approach. These developments forced professionals in private companies and public bodies alike to rethink their roles and the ways to do business. Thus, discussions were, and are still, being held within many consortia to (re-)organize themselves in order to deliver retrofits with ease, performance and cost efficiency. Builders are intensifying and extending the integration of supply chains to deliver suitable solutions. In the same vein, this implies that companies are focusing on the tasks they themselves are good at and able to invest in. Entire supply chains need to become more client-focused. In the case of #ENEXAP, a lot was asked from the professionals involved. The occupants were eager to keep modifications already made to their homes, including the measurements for saving energy and generating durable energy mainly via solar panels. They also asked for additional changes to their home, which made matters for consortia even more complex to handle (Oostra 2015a).

## **5. Discussion and conclusions**

The decisive impacts of the housing sectors on the development of the EU countries, economies, socio-political constellations, technologies and environmental footprints are widely recognized, not forgetting the mutual dependencies between all these spheres, regionally and country by country. In reality, severe barriers are still being met across the EU member countries, such as highly uncertain housing demand, prolonged project development times, late-arriving local public services, still-missing infrastructure, obvious needs for change in involved organisations and supply chains, changing preferences within wider social and institutional context, etc. Thus, we are herein arguing that, for many national stakeholders, it is far from clear how the transition of the EU housing sectors could be directed towards the socio-politically balanced, economically integrated, technologically advanced and high-sustainability sectors we would like them to be, let alone what key roles and tasks stakeholders should become engaged in. This uncertainty triggered us to write this joint paper and explore what kinds of radical elements could be implanted into national residential development programmes within the EU region. For this purpose, we have diagnosed the prime Finnish and Dutch experimental programmes in the previous sections. Relying on the 3-area diagnosis framework introduced in section 2.1, we would like to put forth a set of the suggestions for making radical progress as follows.

For ensuring (1) clearly and radically directed residential programmes, we suggest that key public decision making bodies, at a governmental, regional and/or city/municipality level, or an organisation that is appointed to represent one of these, define clear goals with support from some key stakeholders, daring to be frontrunners. These goals are set (1a) to improve outcomes on each

of the socio-political, economic, institutional, technological and environmental contexts, (1b) to unite stakeholders in terms of balancing their aims and benefits, (1c) to stimulate the sector to include other (only value adding) stakeholder groups in order to be able to reach goals and overcome barriers to be met, and (1d) not to be afraid of asking for radical innovations on key dimensions, such as living quality, space, technical performance, public and private services, mobility, costs, etc. The attainment of ambitious goals and the realization of wide action plans both start with small-scale pilot projects and alike in order to allow for the evaluation and re-setting of goals before programmes are actually started and desired innovations are becoming up-scaled. The Finnish and Dutch experience with the pilots and programmes have proven that such an approach is realistic.

For forming (2) radical networks, we suggest that a range of alternative networks be classified in terms of (2a) developing new key entrepreneurial roles that stakeholders can assume, (2b) initiating multi-dimensional, causal links between different stakeholder/party roles, (2c) leaving room to introduce novel expertise and insightful stakeholders to deal with missing expertise, to advocate, facilitate, enable and moderate during every phase of the (sub-)programme, (2d) evolving memberships through the phases of the programme and beyond, (2e) making key decisions, activities and tasks included in each network class transparent for all to criticise, while not hampering the creativity necessary for innovation and (2f) innovating all kinds of institutional, digital and physical supportive systems and tools that parties can rely upon. A programme directorate then compares gains and losses by each network class, chooses the most radically viable ones and plans networking sub-programmes accordingly directed at upscaling.

For enhancing (3) radical learning, we suggest that a range of alternative ways of learning, exploiting existing knowledge and creating new solutions, be selected and planned by learning areas, to arrive at: (3a) a flexible, highly sustainable market and better knowledge of user preferences in relation to changing demographics, public, private and third sectors, built environment, nature, etc., (3b) product and process innovations, incremental/disruptive, solo/co-innovated, co-funded, given/openly competed, scaled up/down, etc., (3c) new rules and regulations to mend hampering or missing legislation, on city/country/EU levels, by areas and units, etc., (3d) affordable prices, performance improvements and guarantees for stakeholder groups and participant roles, home/apartment/house types, public and private buildings, infrastructure, etc., (3e) improvement of architectural quality, environmental quality and building quality to enhance the realisation of appealing cities, attractive country-sides, meaningful places, true well-being, environmental sustainability, personalised living, inclusive society, regional prosperity, etc. and (3f) commitment from stakeholders to take on new roles and responsibilities designated to realise the goals set and provide performance warranties. The members of the programme compare the alternative routes, choose the most effective ones and integrate them accordingly in designated sub-programmes to start the next learning cycle.

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# Research Road Map on Construction in Brazil: method and results

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## Abstract

The purpose of this article is to present the method used for preparing the Research Road Map on Construction in Brazil and the results of this study that involved a broad participatory process. Academia and the private sector, with the participation of the public sector, jointly reviewed and proposed strategies, under the leadership of two institutions: The Brazilian Chamber of the Construction Industry (CBIC) and the Brazilian Association of Technology of the Built Environment (ANTAC). Although elaborating strategic proposals normally involves a complex approach, a working method was chosen that simplified this procedure. A more orthodox approach would have required mounting an extensive data survey, and undertaking numerous analyses and diagnoses; a wide spectrum of research sources would have been needed for this. A shorter method was adopted, commencing with the preparation of a document that described inter alia the resources that already existed for the production of STI in the Built Environment, and that indicated the level of subject-relevant collaboration existing between academia and industry. This document analysed the main postgraduate centres relevant to the subject in Brazil. A series of challenges to be confronted by the construction industry was also identified, as well as various issues that needed to be resolved prior to tackling them. The document also emphasized the need to establish an STI policy for the construction industry. The second step was to hold five thematic workshops, bringing together experts from academia, government agencies, and companies and their offshoots. They hosted 318 guest participants. Given their expertise and the dynamic interface established, the data collection, analysis and diagnosis phase was avoided, and the participants progressed quickly and confidently to formulate a set of consistent and relevant strategies. The output from these workshops led to a set of 19 strategic lines of research. Nine obstacles were identified that needed to be overcome, and a description was included of the type of STI infrastructure required for the successful of their implementation. Six strategic projects for developing STI, together with four strategic public policies, were proposed and detailed for overcoming these barriers and for deploying the required STI infrastructure.

**Keywords:** Brazil, research road map, construction, construction industry, technology foresight

# 1. Context and working method

In 2002, the Brazilian Association of Technology of the Built Environment (ANTAC), with support provided by the Ministry of Science, Technology and Innovation, the Ministry of Development, Industry and Foreign Trade, and the Ministry of the Cities, issued a document called "The Strategic Plan for STI in the Built Environment with a focus on Housing Construction". The aim of the document was to establish strategic priorities for actions to promote Science, Technology & Innovation (STI) in Brazil (ANTAC, 2002). While this document was useful for guiding public sector STI initiatives, the Construction Industry, regardless of its key role in Brazil's sustainability, continued to be disregarded as a priority STI development sector. Furthermore, the initiative failed to change corporate culture concerning innovation and did nothing to encourage companies to work more closely with academia. ANTAC brings together and represents the community of researchers and technical experts in the field of Technology of the Built Environment.

In 2007, the Brazilian Chamber of the Construction Industry (CBIC) and its partners launched the Technological Innovation Project (TIP) with a view to "making technological innovation an inseparable part of the competitive strategy of the construction sector and its companies throughout the entire supply chain" (CBIC; NGI, 2009). Completed in 2009, the TIP study proposed a range of development projects needed to boost innovation in the sector. ANTAC was invited by the CBIC to proceed with one of these projects: "Project 7 - Science and Technology for Innovation in Construction." CBIC represents the construction industry players from a political standpoint, promotes the integration of them at the national level, and serves as a mouthpiece for 79 construction trade unions and employer associations in Brazil's 26 states and the Federal District.

An opportunity therefore arose for addressing the issue in a new light: by broadening the goal of Project 7, the academic and private sectors, with public sector participation, joined forces to review and propose new strategies as a first step towards formulating an STI Built Environment Policy for the country. This resulted in the emergence of the Brazilian Research Road Map on Construction.

While strategy formulation is usually a complex, multiphase process, the working method adopted for Project 7 was eminently straightforward. It was decided that the strategies would embrace an STI policy that would genuinely enable the construction sector to evolve and thus contribute more substantially to the economic, social and environmental sustainability of the country. More wide-ranging discussion, although it would have helped to shape more precisely the three dimensions involved, would not have changed the core premise. It was noteworthy that, notwithstanding the abovementioned studies, stakeholders had made little headway in their approach to STI. This was also the case with the government agencies responsible for formulating STI policies.

The next step in the process was also simplified: how to reach this goal? An orthodox approach would have meant exhaustively scrutinizing a mass of data, analytical and diagnostic studies. Research would have needed to focus on many different fronts: research institutions and

universities; laboratories; companies and their various representative associations; public agencies; and entities responsible for formulating and promoting STI policies. It would also have been necessary to examine similar studies already done in countries such as Ireland (ICSTI; FORFÁS, 1999), France (Bougrain and Carassus, 2003), Australia (Hampson, 2004), Denmark (National Agency for Enterprise and Construction, 2006), United Kingdom (Department of Trade and Industry, 2002; Edkins et al., 2008), South Africa (Rust et al., 2008), USA (National Research Council, 2009), and New Zeland (Bates and Kane, 2009), as well as the countries of the European Union (ECTP, 2005a and 2005b; Goodier et al., 2008) or even larger groupings (Barrett, 2005; CIB et al., 2010).

The adopted route was in fact considerably shorter, starting with the drafting of a document with a number of clear goals. One of the goals of the exercise was to examine the existing infrastructure for producing construction industry-related STI, paying particular attention to the level of cooperation in STI between academia and the productive sector on the subject. The paper listed the main postgraduate centers working on STI in the Built Environment in Brazil, identifying their main active lines of research, the precise subjects being researched, their prospects, and the challenges faced. Reference was also made to the many challenges still to be faced by the civil construction industry, including various bottlenecks that needed to be surmounted. Finally, the paper underscored the need to establish an STI policy for the sector and discussed the opportunity for creating a specific Sector Fund (Cardoso, 2011).

The second decisive step was to organize five thematic workshops bringing together experts from academia, from companies and their representative associations, and from government agencies. These workshops were intended to cover the main thematic areas of Built Environment Technology.

The workshops were held between October 2011 and October 2012. They involved a total of 318 invited participants, including 88 senior research professors from 29 Brazilian educational and research institutions, and one from abroad. The expertise of the participants and the positive energy generated in the workshops created substantial synergy and convergence of ideas, while avoiding the usual data collection, analysis and diagnosis phases, and resulted in the rapid and reliable formulation of coherent, relevant strategies.

The thematic areas addressed in the five workshops were as follows (Cardoso, 2012):

- **Workshop 1 - Construction systems and processes and production management:**

- ☐ Production management: quality, productivity and sustainability.
- ☐ Rationalization, innovative systems and construction processes.

- **Workshop 2 - Building materials and components:**

- ☐ Innovation in materials and components for sustainable development.



- Innovation in materials and components to improve productivity in building construction.

- Materials and components innovation to improve building performance.

- **Workshop 3 - Water, Energy and Comfort:**

- Water use in buildings.

- Energy use in buildings.

- Acoustics in buildings.

- Comfort and energy on an urban scale.

- **Workshop 4 - Project Design, Use and Operation:**

- Design process management.

- Operation and maintenance of buildings (Facilities Management) and post-occupancy evaluation.

- Information and Communications Technology and Building Information Modeling (BIM).

- **Workshop 5 - Cities:**

- Urban infrastructure.

- Housing management.

- Real Estate.

## **2. Results: Research Road Map on Construction**

The workshops resulted in a three-part Research Road Map on Construction in Brazil (Cardoso, 2013):

- Proposition and description of 19 strategic lines of research in the Built Environment;
- Identification and description of nine obstacles to be overcome and the STI infrastructure required for the successful implementation of the proposed strategic lines of research;
- Proposition and description of projects for developing STI, together with four strategic public policies for overcoming these barriers and for deploying the required STI infrastructure.

## 2.1 Strategic lines of research for STI in the Built Environment

The proposals put forward in the workshops envisaged 19 strategic lines of research for STI in the Built Environment, covering the different life cycle phases of a project:

- Line 1 - Carrying out studies on (i) competitiveness and value creation by conducting research on innovation-inducing mechanisms in companies; (ii) the economics of the construction sector; (iii) articulation and modernization of the supply chain; (iv) public and sectoral policies; and (v) improving the professional competencies and productivity of the workforce at every level. Particular efforts need to be focused on micro, small and medium-sized firms.
- Line 2 - Strengthening fundamentals, methods and tools with a view to scaling up sector-relevant practices in the real estate segment in areas such as: improving decision-making processes and strategic and tactical planning in companies; improving the presentation of real estate products; identifying the concerns and needs of different consumers; defining the relationship between business and government with regard to urban planning and environmental regulations, and the operationalization of instruments such as public-private partnerships, urban planning schemes and the granting of concessions.
- Line 3 - Development of design process management systems in public and private works focused on organization, contract and coordination models.
- Line 4 - Development of collaborative design processes using Information Technology in Construction (ITC) and Building Information Modeling (BIM) concepts and tools.
- Line 5 - Development of a knowledge management system to support projects to ensure the sustainability and performance of buildings and urban infrastructure. This knowledge management system involves setting up and using databases and other information sources that will contain inter alia: key environmental parameters maps; information on materials deterioration agents; reference service life of materials, components and urban elements; thermo-hygrometric behavior of materials and components; acoustic characteristics of wall materials; technical catalogs and Building Information Models (BIM) of materials and components; performance evaluation inventories according to the user's point of view; inventories on use, operation and maintenance indicators; inventories of socio-environmental sustainability indicators; inventories of the generation potential, consumption and end-use of energy in cities; inventories of urban solid and liquid wastes, and their power generation capacities; data on the activities of real estate markets in Brazilian cities.
- Line 6 - Development of a simplified method of Life Cycle Assessment (LCA) applicable to different-sized companies, in order to facilitate the introduction of verifiable Environmental Product Declarations (EPDs). This involves e.g. defining the scope of each product, as well as its governance models and Product Category Rules, etc.
- Line 7 - Development of models, methods, tools (including test equipment) for evaluating the continuous development and improvement of performance evaluation technology for buildings and urban infrastructure.
- Line 8 - Development of a National Codes of Practice System and a knowledge management system to support it, including the development (creating and assembling) and application (dissemination and use) of best design practices, and the construction, use,

operation and maintenance of the buildings and urban infrastructure systems and elements, including control practices at every stage.

- Line 9 - Development of ITC in the design, construction, operation and maintenance of buildings and urban infrastructure and Building Information Modeling (BIM) at the design, construction, control, use, operation and maintenance stages of buildings and urban infrastructure.
- Line 10 - Development of components, systems and innovative processes, and of open industrial systems based on principles such as modular coordination, easy connectivity, increased productivity, reduced product delivery times, improved performance and durability, lower environmental impact during the product life cycle, lower consumption of materials and lower losses, etc.
- Line 11 - Development of materials, components, equipment and eco-efficient systems, and improvement of the eco-efficiency of existing materials, etc., always considering the typical life cycle of the built environment. This initiative should include finding solutions to improve the durability of materials, components, equipment and systems, to assess their prospects for dematerialization, potential reuse, recycling or regeneration, and to reduce losses by employing the correct tools for selecting materials.
- Line 12 - Development of research on water use in buildings, to include exploring concepts, methods and tools to reduce user demand. Also to study possible safe ways to ensure domestic water supplies from alternative sources, to encourage the rational use of water, to design cold and hot water, drainage and sewerage systems for buildings, and to evaluate climate change and the performance of building systems.
- Line 13 - Development of research on energy use in buildings, to include exploring energy-related concepts, methods and tools used in buildings with regards to natural ventilation, thermal performance, bioclimatology natural lighting, and using models to simulate energy-efficient buildings.
- Line 14 - Development of studies on concepts, methods and tools related to buildings acoustics: acoustic characteristics of internal and external sound-reducing materials; floor-insulating materials and technologies; vibration; subjective acoustics; and using numerical and computational simulation.
- Line 15 - Development of integrated technological and management production systems. Exploring the development of methods, tools, indicators and their respective benchmarks focused on production systems management, involving items such as costs, target dates and risk management, people management, logistics and supply management (procurement), and clean production.
- Line 16 - Development of fundamental concepts, methods and tools for consolidating the use, implementation, maintenance and adaptation of the concepts concerning the use, operation, maintenance, post-delivery and security of products, and the management of facilities. Development of methods and tools for commissioning buildings and their parts, and urban infrastructure; post-handover and management of occupied buildings; automation and oversight of buildings and urban infrastructure management procedures; control and oversight of building and infrastructure use; costs management during warranty periods; management of operating costs, maintenance and life cycle of buildings and urban infrastructure.

- Line 17 - Development of urban-wide design methods and interventions aimed at integrating urban morphologies with infrastructure and housing systems. This should involve considering topics such as: the growth dynamics of cities and rural areas, including both small and large size cities; risk prevention, security, accessibility, comfort, energy, urban planning and the adaptation of buildings; the development of inclusion and different living styles in cities; classification and upgrading of the housing stock; and accessible and appropriate information technologies for participatory decision-making and activities.
- Line 18 - Development of models for housing production programs, and of public policy proposals for housing, taking into account the diversity of cities and different income levels and market segments. Studies to be carried out on ways to improve existing practices.
- Line 19 - Development of fundamentals, methods and tools for environmental comfort and energy on an urban scale, involving topics such as: the behavior of urban heat islands (UHI); the impact of urban geometry and building density on accessibility to natural resources, and in response to local climate change; the development and measurement of urban thermal comfort indices; thermo-hygrometric behavior of native vegetation clusters in urban areas; thermo-hygrometric behavior of urban building materials and components, and the effects of the reflection coefficient (albedo) in urban areas.

## **2.2 Obstacles to be surmounted and STI infrastructure required**

The workshops identified the obstacles blocking successful development of the strategic lines of research:

- Distancing between academia and the market and between academia and the public sector;
- Poor liaison between construction industry players;
- Problems with access to knowledge;
- Conservatism of construction industry players;
- Short-term view held by construction industry players;
- Legal constraints affecting development of STI;
- Use of inadequate mechanism for evaluating research by academia focused on technological innovation;
- Unavailability of data in support of STI; and
- STI held back by shortage of standards and regulations as well as by their limited application.

The workshops also identified and described STI infrastructural limitations vital for successful development of the strategic research lines in the laboratorial, human, and financial resources areas.

Further details can be found in Cardoso (2012).

## **2.3 Strategic projects for developing STI and strategic public policies**

The discussions on ways to surmount obstacles and secure the necessary infrastructure for STI to ensure the successful development of the strategic research lines led to six strategic projects for developing STI in the Built Environment being identified and defined:

- Employing STI development models to bring academia, the market and the public sector closer together;
- Enhanced cooperation between construction industry players;
- Increased knowledge dissemination;
- Scaling up research evaluation mechanisms for research focused on technological innovation;
- Increased resources for STI; and
- Better human resources training for STI.

Finally, discussion on ways to overcome the obstacles identified and to guarantee an infrastructure for STI led to four strategic policies being identified and defined:

- Tax incentives to promote investment in STI;
- Industrial policy for development of the construction supply chain;
- Changes in public procurement and contracting; and
- Increased access to information on STI.

More details can be found in Cardoso (2012).

## **3. Final comments**

The Research Road Map contributes to filling a gap by working up strategies for formulating an STI policy for the construction industry focused on the Built Environment in Brazil. The process of strategic formulation does not however end with this Road Map. The strategic lines of research and the proposals put forward for projects to surmount obstacles and barriers and for public policies vital for achieving an STI policy for the sector call for a more accurate definition of objectives. Action plans need to be drawn up for each strategic research line, and people appointed to be responsible for taking them forward successfully. Targets, deadlines and a procedural road map are also vital components, together with the necessary human, technological, scientific and financial resources and strategies for obtaining them. Rapprochement between academia, the market and the public sector is essential for moving this process forward.

Notwithstanding its limitations, the Research Road Map on Construction provides guidance for decision making on investments in STI by construction companies and other sector stakeholders and government funding entities. The Road Map also steers research institutions towards the lines of research that need to be adopted, thus contributing to the modernization of the construction sector and quickening the pace of innovation therein. Above all, it is hoped that the strategies

proposed will lead to the effective formulation of an STI policy for a sector that is vital for Brazil's economic development and the welfare of its population.

Although the Research Road Map on Construction has been developed for Brazil, the results are similar to those of studies done in other parts of the world, which suggest that the construction sector depends heavily on the performance of the players involved in the industry as a whole. All share inherent views on the need to develop STI, and confront similar obstacles, regardless of the level of development of the different countries. A worthwhile initiative would be to conduct a comparative study on the methodological approaches of the studies cited above (and others) and on the data outcomes produced on the situation of the construction sector, with a view to gaining further invaluable knowledge about the sector's basic characteristics.

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# Construction in Developing Countries: Current imperatives and potential

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## Abstract

The study is a review of the state of knowledge on the construction industries in developing countries and an attempt to explore new ways to address the task of developing the industries to enhance their capabilities to deliver the buildings and infrastructure which the countries require to improve the quality of life of their citizenry. The nature of the long-term national development task of the developing countries is discussed to provide the background for the examination of the ways in which the construction industry can contribute to the fulfilment of the broad aspirations of the nations, and the attainment of their developmental goals.

The objectives are: to consider the needs for built items in the developing countries in the context of national development; to examine the challenges and problems facing the construction industries and consider the usual solutions suggested; to explore possible new, contextually relevant ways in which the industries can be developed and their performance improved; and to consider how construction in developing countries can leapfrog developmental stages, and draw lessons for the industrialised countries.

The study is based on an analysis of data on existing needs of construction items in the developing countries; and a review of literature on the development of the industries in these countries. An analysis of relevant key overarching issues and factors in the economies of the developing countries and a consideration of the construction industry from its basic nature, informed the drawing of inferences on new ways of improving the performance of the construction industries in the developing nations. The possibility of leapfrogging in many areas is explored. It is suggested that the construction industries in the developing countries have the potential to offer lessons for their counterparts in industrialised countries.

**Keywords:** construction industry, developing countries, infrastructure, future, leapfrog, lessons



## **1.0 Introduction**

The construction industries of the developing countries have been studied since the mid-1960s. The earliest works were by the University College Economics Research Group (UCERG) which undertook many studies for the World Bank and International Labour Office. The development of knowledge on the subject is presented by Ofori (1993, 2012a). This study is a review of the state of knowledge on the construction industries in developing countries. Its aim is to explore new ways to develop the industries. The objectives are to:

1. consider the needs for built items in the developing countries in the context of national development
2. examine the challenges and problems facing the construction industries which must fulfil these needs and consider the usual solutions proposed
3. explore possible new, contextually relevant ways in which the industries can be developed and their performance improved
4. consider how construction in developing countries can leapfrog developmental stages, and draw lessons for the industrialised countries.

The study is based on an analysis of data on the needs of the economies and how construction can contribute to their realisation; a review of recent literature on the development of construction industries; and an analysis of the construction industry from its basic principles. The possibility of leapfrogging stages and lessons for industries in industrialised countries are considered.

## **2.0 Development needs, goals and programmes**

### **2.1 Washington and Post-Washington Consensus programme**

Various approaches have been taken to set the poorer countries on a path to long-term development. The Washington Consensus of economic development which was applied by the World Bank, International Monetary Fund, United Nations agencies and the US government over the 1980s and 1990s comprised (Williamson, 2004): Fiscal discipline; Public expenditure priorities – moving them away from subsidies and administration; Tax reform; Financial liberalisation; Exchange rates - managed to induce growth in non-traditional exports; Trade liberalisation; Increasing foreign direct investment; Privatisation; Deregulation; Secure intellectual property rights; and Reduced role for the state. This ‘package’ was intensely debated and criticised (Williamson, 2004). It went through many changes. By the late 1990s, it comprised: sound fiscal and monetary policies; broad-based taxes levied at moderate rates; market determination of prices and quantities; discriminating use of infant industry protection; an acceptance of foreign direct investment; active government provision of education, health care, and infrastructure; and anti-poverty programmes. Stiglitz (2004) presents a sharp critique of the approaches in the 1980s and 1990s, and concludes that, given the differences among countries, there cannot be any consensus as a one-size-fits-all solution cannot work.

The Millenium Development Goals (MDGs) provided the framework for socio-economic development from 2000 to 2015. Progress was made in many areas including poverty reduction (in 1990, half of the population in developing countries lived on less than \$1.25 a day, that proportion dropped to 14 percent in 2015; the number of people living in extreme poverty declined from 1.9 billion in 1990 to 836 million in 2015); and primary education (net primary school enrolment rate in developing regions reached 91 percent in 2015, from 83 percent in 2000; the number of out-of-school children of primary school age worldwide reduced by half, to 57 million in 2015, from 100 million in 2000) (United Nations, 2015a). The progress in connectivity is impressive. By 2015, 95 percent of the world's population was covered by a mobile-cellular signal; the number of mobile-cellular subscriptions grew tenfold over 15 years, from 738 million in 2000 to 7 billion in 2015. Internet penetration grew from 6 percent of the world's population in 2000 to 43 percent in 2015; and 3.2 billion people were linked to a global network of content and applications.

However, many of the targets were missed and much remains to be done (United Nations, 2015a). For example, in 2015, 91 percent of the global population was using an improved drinking water source, compared to 76 percent in 1990; 147 countries had met the drinking water target, but only 95 countries had met the sanitation target and 77 countries had met both targets. Worldwide, 2.1 billion people had gained access to improved sanitation, but 29.7 percent of the urban population in the developing countries still lived in slums in 2014 (although this fell from 39.4 per cent in 2000).

## 2.2 Post-2015 Development Agenda

The Post-2015 Development Agenda is built around the attainment of the Sustainable Development Goals (SDGs) (United Nations, 2015b). The SDGs are presented in Figure 1, categorised with respect to relevant aspects of construction. United Nations (2015b) considers the SDGs as being integrated and indivisible, global and universally applicable, taking into account different national realities, capacities and levels of development and respecting national policies and priorities. Unlike the previous 'consensus' approach, it recognises that each government would set its national targets guided by the global level of ambition but taking into account national circumstances; and decide how the targets should be reflected in planning processes, policies and strategies. Countries could use different visions, models and tools, in accordance with their contexts and priorities.

<p><b>Basic human and national needs</b></p> <ul style="list-style-type: none"> <li>* Goal 1. End poverty in all its forms everywhere</li> <li>* Goal 2. End hunger, achieve food security and improved nutrition and promote sustainable agriculture</li> <li>* Goal 3. Ensure healthy lives and promote well-being for all at all ages</li> <li>* Goal 4. Ensure inclusive and equitable quality education and promote lifelong learning opportunities for all</li> <li>* Goal 5. Achieve gender equality and empower all women and girls</li> </ul>	<p><b>What construction must do</b></p> <ul style="list-style-type: none"> <li>* Goal 9. Build resilient infrastructure, promote inclusive and sustainable industrialization and foster innovation</li> <li>* Goal 11. Make cities and human settlements inclusive, safe, resilient and sustainable</li> </ul> <p><b>Some of construction's results</b></p> <ul style="list-style-type: none"> <li>* Goal 6. Ensure availability and sustainable management of water and sanitation for all</li> <li>* Goal 7. Ensure access to affordable, reliable, sustainable and modern energy for all</li> </ul>
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* Goal 8. Promote sustained, inclusive and sustainable economic growth, full and productive employment and decent work for all	
<b>Inputs and methods of construction industry</b> * Goal 12. Ensure sustainable consumption and production patterns * Goal 13. Take urgent action to combat climate change and its impacts * Goal 14. Conserve and sustainably use the oceans, seas and marine resources for sustainable development * Goal 15. Protect, restore and promote sustainable use of terrestrial ecosystems, sustainably manage forests, combat desertification, and halt and reverse land degradation and halt biodiversity loss	<b>Broad international goals</b> * Goal 10. Reduce inequality within and among countries * Goal 16. Promote peaceful and inclusive societies for sustainable development, provide access to justice for all and build effective, accountable and inclusive institutions at all levels  <b>A key international ‘wherewithal’</b> * Goal 17. Strengthen the means of implementation and revitalize the Global Partnership for Sustainable Development

Figure 1 Sustainable Development Goals

## 2.3 Role of construction in meeting development needs

The subject here is to consider the contribution the construction industry can make to the effort to find viable solutions to the development challenges of developing countries. The literature provides evidence on the potential of construction in development. Authors such as Lopes (2009) continue the work began in the 1960s at UCERG on the developing countries (Ofori, 1993). Ofori (2012a) and Zawdie and Murray (2008) examined how the construction industry could help to attain the MDGs; and Ofori (2015) investigates its potential in the pursuit of the SDGs. Construction influences development mainly through the provision of the physical infrastructure. Easterly and Levine (1997) found that infrastructure is strongly and significantly co-related with economic growth. Fedderke and Bogetic (2006) found a long-term relationship between infrastructure and growth in South Africa. Calderon and Servén (2008) found that Africa's economic growth per capita would be 1.0 percent higher if it had South Korea's infrastructure. In a study on Africa in general, Escribano *et al.* (2008) found that infrastructure has a substantial effect on total factor productivity. Foster and Briceño-Garmendia (2010) found that: infrastructure has been responsible for over half of Africa's recent improved growth performance. Models for assessing competitiveness of countries give much weight to infrastructure provision (Schwab, 2016). Thus, whereas the Post-2015 Development Agenda and the SDGs themselves continue to be subjects of debate (Ofori, 2015), there is a consensus on the importance of infrastructure for sustainable development.

Infrastructure needs are greatest in Sub-Saharan Africa, as shown in Table 1. Its infrastructure networks increasingly lag behind those of other developing countries and are characterised by missing regional links and stagnant individual access; its infrastructure services are twice as expensive as elsewhere. Power is Africa's largest challenge; 30 countries face regular shortages.

The role of the construction industry in economic growth and national development is well recognised in developing and industrialised nations. As an example of the latter case, an element of the vision for UK construction by 2025 is an industry “that drives and sustains growth across the entire economy by designing, manufacturing, building and maintaining assets which deliver genuine whole life value for customers in expanding markets both at home and abroad”. Governments of many industrialised countries have broader expectations of the construction industry than in developing nations. In New Zealand, the government noted: “At home, we need to address a persistent productivity gap to make sure our businesses remain competitive on the world stage. Infrastructure will play a key role in lifting productivity and ensuring we can take advantage of opportunities in the global economy...” (p. 7). Government of Ireland (2014) observed that in its path towards economic recovery (following the 2008 economic and financial crisis), Ireland needed a strong and sustainable construction industry, because it needed good quality homes and high-quality commercial developments to underpin recovery and growth, and infrastructure fit for the future. Sugii (1998) suggested: “From the perspective of building social infrastructure efficiently, the improvement of labour productivity in the construction sector will lead to greater efficiency and international competitiveness of the overall economy, as well as to the long-term development of the construction industry”. Thus, a strong and efficient construction industry is a strategic national asset and it is necessary to explore its full potential, from the perspectives of developing countries.

*Table 1 Africa’s Infrastructure Deficit*

<i>Normalized units</i>	<i>Sub-Saharan Africa low-income countries</i>	<i>Other low-income countries</i>
Paved-road density	31	134
Total road density	137	211
Main-line density	10	78
Mobile density	55	76
Internet density	2	3
Generation capacity	37	326
Electricity coverage	16	41
Improved water	60	72
Improved sanitation	34	51

Source: Yepes, Pierce and Foster (2008)

Note: Road density is measured in km per 100 square km of arable land; telephone density in lines per thousand population; generation capacity in megawatts per million population; electricity, water, sanitation coverage in percentage of population.

## 3.0 How ready is construction?

### 3.1 Construction industry problems and challenges

The problems and challenges of the construction industries in developing countries are well catalogued. The findings of two recent studies in Africa can be outlined. Windapo and Cattell (2013) found the following in South Africa (in rank order): increases in the costs of building materials; access to affordable mortgage/credit; high interest rates; high rate of enterprise failure/delivery capacity and performance; mismatches between available skills and required skills; availability of infrastructure; external influences such as government legislation; availability of suitable land; public-sector

capacity; poverty; critical global issues/globalisation; procurement practices/ capacity for sustainable empowerment; and technology. In a study of 323 public-sector projects in Botswana, Ssegawa-Kaggwa *et al.* (2013) found these deficiencies in the construction industry: (a) Deficiencies of clients – inadequate competent human resources, inadequate project briefs, lack of project management approach, lack of effective project supervision, lack of a prompt payment system for suppliers; (b) Deficiency in the regulation of professionals, contractors and the procurement process – ineffective and inefficient regulation of project procurement process, ineffective regulation of consultants, ineffective regulation of contractors; (c) Deficiencies of suppliers – incompetent consultants, inefficient and ineffective contractors, unreliable utility providers; and (d) Deficiencies of facilitators (such as firms which provide information).

Planning Commission (2013) highlighted these constraints of the construction industry in India: less than 6 percent of workers had structured training; lack of a unified national regulatory framework for construction firms; lack of an efficient and stable regime for dispute resolution; shortcomings in contracting procedures (they are cumbersome and costly); lack of standardisation of core contract conditions, procedures and evaluation criteria; time and cost over-runs; high operation, maintenance, and financing costs; low access to institutional finance (it is inadequate and costly); poor state of technology leading to inefficiencies, wastage and low value added; poor quality of construction; low productivity growth; and low investment in research and development (R&D).

Some examples of new challenges facing construction industries in developing countries which have not yet been addressed can be raised. The first of these is the high volume of uncompleted buildings. Williams (2015) found that, in Ghana, a study of over 14,000 local government projects showed that about one-third are never completed, although these were small projects (with a median budget of US\$36,000 and scheduled duration of five months). The second issue is the large volume of debt owed to construction companies by public-sector clients. Whereas delays in payment have been among the key problems highlighted by researchers for many decades (Sambasivan and Soon, 2007), the situation, in many developing countries, has significantly worsened, with the delays running into many years (Fugar and Agyakwa-Baah, 2010). This situation will require a novel approach to solve, considering the size of the debt compared to annual public-sector development budgets and the need to continue to fund current and future projects. The third issue is the increasing level of importance of stakeholders including traditional rulers, community leaders and ordinary people, now well informed, and empowered by mobile telephony (Thasarathar, 2016). Also important is the emergence and growth of non-governmental organisations (NGOs) dedicated to monitoring projects, such as Road Watch in the Philippines, and the emergence of multi-stakeholder initiatives such as the Construction Transparency Initiative (Ofori, 2016).

The construction industries in all countries face challenges and problems. Examples of recent reviews of construction industries in industrialised countries are now considered. The weaknesses of the UK construction industry identified in a strategic review were (HM Government, 2013): (a) low vertical integration in the supply chain, with high reliance on sub-contracting which often leads to fracture

between design and construction management and a fracture between the management of construction and its execution leading to lost opportunities to innovate; (b) low investment in R&D and intangible assets; (c) lack of collaboration and limited knowledge sharing; and (d) high construction costs in comparison with the industry's competitors, driven by inefficient procurement and processes. It was suggested in the review that the industry could significantly enhance its performance (HM Government, 2013). The ambition, under the strategy, was to achieve by 2025: 33 percent reduction in both the initial cost of construction and the whole life cost of assets; 50 percent reduction in the overall time from inception to completion for new build and refurbished assets; 50 percent reduction in greenhouse gas emissions in the built environment; and 50 percent reduction in the trade gap between exports and imports for construction products and materials.

The issues to be addressed under Ireland's construction industry strategy included (Government of Ireland, 2014): a strategic approach to the provision of housing, based on real and measured needs; continuing improvement of the planning process, striking the right balance between current and future requirements; availability of financing for viable and worthwhile projects; ensuring the country has the tools to monitor and regulate the sector so that it underpins public confidence and worker safety; and ensuring a fit for purpose sector supported by a highly skilled workforce achieving high quality and standards.

The proposals being made in the developing and emerging economies for addressing their construction challenges are similar to those in the industrialised countries. The aim of Malaysia's "Construction Industry Transformation Programme 2016-20" is: "a transformation of today's construction industry into a modern, highly productive and sustainable industry that is able to enjoy continued growth and enable Malaysian companies to compete with international players whether domestically or abroad". The programme has four strategic thrusts: Quality, Safety and Professionalism; Environmental Sustainability; Productivity; and Internationalisation.

### **3.2 Developing country exceptionalism**

It is necessary to consider the special nature of the industries in developing countries. Ofori (2012b) shows that there are differences between the construction industries in industrialised countries and those in developing countries with respect to appropriate responses to the inherent features of construction owing to the differences in resources, sophistication of their administrative systems and maturity of their industries; differences in the industries' capabilities and performance; and how they deal with the industry's driving forces. Ofori (2012b, p. 8) argues that: "As, in the developing countries, resources for implementing the policies and programmes are limited, the need is great and time is of the essence, it is important that the knowledge that forms the foundation of the policies and programmes should be sound and practically and directly relevant". For example, Foster and Briceño-Garmendia (2010) estimated the cost of Africa's infrastructure needs at about \$93 billion per year in capital, and operation and maintenance expenditure (required capital spending on power, on water supply and sanitation, and on transport were 26.7, 14.9 and 8.8 billion per year respectively). The

fragile states face an impossible burden and even resource-rich countries lag behind. The construction industry also has a greater technical, professional and social responsibility in the developing countries because the clients and users are often not knowledgeable about the construction process; and the legislative and administrative systems are relatively weak.

Thus, the construction industry should: (a) deliver projects which meet the greatest level of performance with regard to the parameters (including new ones here such as affordability, durability, social performance); (b) contribute to economic growth and long-term national development; (c) provide employment and enhance incomes; (d) enhance the quality of life of the populace; and (e) further grow and develop as an industry. There is also a need for action across a broad spectrum of areas because the project goals and performance parameters are closely inter-related. For instance, the latest International Monetary Fund (2016) forecasts indicate that the economies of many developing and emerging countries are facing stress, and thus, public budgets are tight. Thus, there should be, initial cost savings so that a bigger volume can be constructed; and higher quality and durability, in order to reduce repair and maintenance needs.

### **3.3 Some ideas for improved industry performance**

Some of the suggestions on improving construction industry performance which have been made in industrialised countries for many decades, but which are only practised in exceptional circumstances could be key in the developing countries. Six pertinent examples could be considered. These are: (a) effective co-ordination and integration of the contributions of members of project teams; (b) project health; (c) community participation in aspects of projects; (d) project governance; (e) post-occupancy evaluation; and (f) best practices. First, many reviews of construction industries highlight the fragmentation of the industries as a negative feature. HM Government (2013) considers the separation of design from construction and reliance on subcontracting as among the most important weaknesses of the UK construction industry. The structures of the construction process which are applied in the former metropolitan nations have been adopted in the different cultural and administrative contexts in developing countries (Ofori, 1993). Some studies consider the project arrangements used in developing countries as contributors to poor performance on projects and highlight the cultural disconnect (Rwelamila *et al.* (1999). Thus, in the developing countries, a fresh approach can be taken. The roles of participants could be based on the selection of the most appropriate persons and teams on the basis of their technical and professional suitability in the context of the project concerned. Local cultural norms should inform the design of contractual arrangements and project relationships, which are, currently, 'foreign'.

The second example is project health: tracking key performance indicators on construction projects while they are underway, to enable action to be taken on them at relevant points has been proposed by some authors (Humphreys *et al.*, 2004). This makes the learning of lessons a dynamic process. Otherwise, as noted in HM Government (2013), lessons are never learnt, owing to the uniqueness of projects, differences in teams for each project and poor data capture, analysis and dissemination in

construction. In developing countries, the idea of maintaining *project health cards* rather than undertaking *project post-mortems* at the commissioning and feedback stages should be fostered.

The third example is the participation of other stakeholders in the construction process. Community participation in various aspects of the construction process, such as design, has not been widely accepted among the design professions (Wates and Knevitt, 1987), and has been applied on projects only as an exception (Moodley and Preece, 2008). The community's involvement can make the design more culturally and contextually relevant; optimise benefits to users and the community; and ease disruptions to the lives and livelihoods of residents. The community's involvement can extend to the operation and maintenance stage when members can provide performance information.

The fourth issue is that of project governance. Construction has a poor reputation among other sectors, as evinced by its score in the BribePayers' Index (Transparency International, 2012). This is more important in developing countries for many reasons. These nations have poor records with regard to corruption, for example, on Transparency International's (2016) Corruption Perception Index, more than six billion people live in countries with a serious corruption problem. The global average score was 43 (out of 100); that for Africa was 33, and for the Asia-Pacific region, 43. Thus, ethics is a key issue, and it should be incorporated into project structures and procurement and contractual arrangements, educational and training programmes in the developing countries.

The fifth example is post-occupancy evaluation (POE) which has also been proposed for many decades (National Academy Press, 2001), but remains highly uncommon. Projects can produce a stream of information for improving their own performance and those of similar ones in future. Such evaluations can be undertaken at regular intervals after the completion of the item. For example, in developing countries where green building benchmarks have not yet been firmly established, the POE could incorporate environmental performance and could be undertaken some years after completion rather than during the design stage, followed by regular assessments. The possibility of establishing a national database on various aspects of the performance of items of construction could be considered. This information could be developed into best practice guides.

The final example is "best practices" (which might cover some of those discussed above). In construction, best practices occur in exceptional situations only. Construction Industry Institute (2015) categorises "best practices" under headings including: Advanced Work Packaging; Alignment – where project participants are working within acceptable tolerances to develop and meet a uniformly defined and understood set of project objectives; Benchmarking and Metrics; Change Management; Constructability; Disputes Prevention and Resolution; Front End Planning; Lessons Learned; Materials Management; Partnering; Planning for Modularisation; Project Risk Assessment; Quality Management; Team Building; and Zero Accidents Techniques. Cain (2003) presents six goals for construction best practice: delighted end users and clients; lowest optimum cost of ownership; elimination of inefficiency and waste; specialist supplier involvement in design; single point of contact for clients; and proof of performance from measurement. Federal Facilities Council (2007)



proposes best practices owners should adopt at various stages of projects to minimise contract disputes. Lahdenpera (1998) suggested actions “to modify the operational modes of the construction industry for the common good”. Considering the needs and circumstances, in developing countries it would be appropriate to apply best practices routinely on all projects.

The availability of information and communication technology makes the wide application of these six practices in developing countries possible. Thasarathar (2016) highlights technological trends in construction including: 3D printing, the Internet of Things (IoT), robotics, drones, cloud computing, infinite computing, reality capture, augmented reality, gaming engines, crowd-funding, crowd-sourcing, generative design, big data and artificial intelligence. He notes that in future, the cloud will place a theoretically unlimited amount of processing power at the disposal of any company, regardless of size, location, or experience, on demand to: solve complex problems; connect to an unlimited number of people to get ideas; and raise capital for projects, through funding techniques such as crowd-funding. As an application for POE, Rogers (2016) suggests that a database from a building information model (BIM) linked to real time sensors can log many metrics to determine the building’s performance against what the designers predicted and the quality of service it provides.

## **4.0 What is to be done?**

The construction industry in each developing country should ask itself: (a) in the changing national and global economic and social developments, what does our nation need from the "built environment" 'sector'? (b) how can the industry be set up to enable the pursuit of innovation and continuous performance improvement? (c) how best can the industry benefit from existing and emerging enablers, such as information technology? Each industry should seek context-specific solutions to its problems and challenges. It should scrutinise its practices and procedures and question assumptions which form their bases of practice elsewhere. For example, In the US, Federal Facilities Council (2007) notes that: "Given the infinite complexities of delivering a building or infrastructure project, the multiplicity of organizations and individuals involved, and the magnitude of the dollars at risk, it is perhaps not surprising that the construction industry has been characterized by an adversarial operating environment that generates disputes and conflicts" (p. 1). Developing countries cannot afford to adopt this “practice norm”.

As another example, Construction Industry Board of UK (1996) proposed a strategy to improve the industry's image. The internal objectives in the industry were: provide better value for the client; improve the achievement of quality, professionalism, efficiency and profitability; and improve the professional relationships between constructors, consultants and clients. The external objectives were: attract greater investment; encourage more construction work to the responsible contractors and consultants; improve environmental and social relationships; attract high-standard recruits; and encourage equal opportunities. One could argue that this range of objectives is what should be attained on projects on a routine basis. In the developing countries, these should be the norm.

Developing countries can leapfrog stages of development. First, the role of the community in projects can be applied through the traditional system of governance and the increasing strength of “development committees” representing particular districts. The chiefs and local committees can contribute to many aspects of the projects in their areas over their life cycle. This will also make stakeholder management necessary, resulting in leadership by the developing countries in that area. The community could pool ownership and crowd fund essential infrastructure and social projects in the area. Construction companies could set up joint venture entities with the communities.

Second, developing countries have the opportunity to derive meaning for, or apply aspects including: construction as a contributor to value and wealth creation; effective, culture-sensitive and contextually-relevant project team selection and dynamics; innovative community involvement in project planning, design, operations and maintenance; effective value chain formation and management, including strategic alliances among firms in design and construction for continuous operations and possibly, formation of multi-disciplinary firms as a norm. Finally, the availability of infinite computing power to the industries in developing countries offers many possibilities. Examples include: (a) enhancing briefing, planning and design processes using augmented and virtual reality; (b) using the capabilities of the IoT – to collect and analyse performance data in operation of items, such as the volume of passengers, trade carried on a road, in order to guide decisions on maintenance or rehabilitation; and (c) small firms using the available computing power to set up effective project and enterprise management systems.

## **5.0 Conclusion**

No construction industry is perfect. There is also no panacea for the challenges faced by the industries. It is important to widen one’s horizon in seeking to improve the industries in developing countries. In construction, only the best is good for the poor. If one thinks of the ideals of construction, that is what the developing countries need. The ideals include: ensuring that each project and each constructed item contributes effectively to national sustainable development, and applying this in awarding and implementing projects; harmonising and aligning motivations and obtaining the maximum commitment and contribution from each project participant; optimising the combination of the participants’ contributions; applying best practices in all aspects of projects; effectively developing the construction industry from each project; and providing leadership to the community. More research is needed to explore the application of best practices and each of the six previously proposed approaches in developing countries. Maturity of the industry might not be a prerequisite in all these cases; it could even be a hindrance. If the construction industries in developing countries apply these ideals, they can teach their counterparts in industrialised nations.

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# Urban Sustainable Resilience Values: Driving Resilience Policy that Endures

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## Abstract

Countries across the globe are likely to face significant challenges in coming years that will test the resilience of their cities. However, there is often a lack of proactive evidence-based analysis of available options and their outcomes as well as indicators of success or progress. Without such analysis it is difficult to clearly gauge progress towards set goals, to improve effective policy development and implementation, and to create an active learning culture that can efficiently and effectively tackle future challenges. The present work offers an introduction to research being done to develop a policy evaluation and implementation framework that can help policy-makers produce more effective resilience policies which are sustainable over time. The term *sustainable resilience* has some usage in the literature but has had limited uptake and has not been formally characterised until now. This new concept creates a clear differentiation from reactive disaster resilience which is often the sole focus of urban policy development. This paper contributes to developing a working concept and guiding principles for urban sustainable resilience policy. This work suggests that sustainable resilience policy will need to take into account the complexity within and between the various systems that form cities, rapidly changing technologies, environmental conditions, and emerging forms of governance. This paper also briefly outlines the methodology that will be used to continue to develop a sustainable resilience policy framework and evidence-based assessment tool.

**Keywords:** resilience, sustainable, policy, evidence-based assessment.

# 1. Introduction

Cities currently host more than half of the world's population, a number which is projected to reach 66% by 2050 (UN, 2014). In 2014, countries such as Australia, Japan, Qatar, the Netherlands and Uruguay had less than 11% of their population living outside of urban settlements (The World Bank, 2015). Cities also generate large percentages of the national gross domestic product (GDP) and are important sources of employment. In Australia for example, 80% of GDP and 75% of employment is produced in cities (Commonwealth of Australia, 2011). Climate change and fast technological progress, among other factors, will bring considerable challenges for urban policy makers and implementers. They will need to be able to keep pace with the unforeseeable and a future that will likely be significantly different from past experience, while also aiming to maintain and increase liveability and social well-being.

This realisation has led to a surge of resilience literature and policies for ecosystems and urban settlements. The academic literature has been particularly prolific in providing different interpretation of the term. A recent literature review for example analysed 172 resilience studies and found 25 distinct definitions of the term “resilience”. Half of the definitions were centred on a specific threat and 40 percent focused on a static (single-equilibrium) view of resilience (Meerow, et al., 2016). Even within disaster focused resilience literature there is a range of definitions. Manyena (2006) for example was able to separate 12 definitions. Policies are thus guided by different understandings of resilience. Davoudi (2014) argues that many of them are in fact driving a new form of “resilient urbanism” which is focused on short-term emergency response rather than long-term adaptive capacity. These are driven by the objective of quickly returning to a state of equilibrium after being affected by sudden external shocks, such as climate events, and often pay little attention to chronic long-term stress sources. These “*high time preferences*”, namely valuing the present above the future, has been argue to generate a perception of time which is incompatible with cycles that shape civilisation. Further to this, Moffat (2014) argues that this short-term vision devalues the key idea of resilience and that “*until time preferences change, progress towards resilience will be very slow, regardless of changes to public policy or technical expertise*”. The concepts of *sustainable resilience* and *sustainably resilient policy* aim to challenge this trend and bring the focus of the debate towards how to deliver urban policies that can be proactive in creating enduring resilience and prompting sustained action.

The present work explores and outlines the concept of sustainable resilience, which has usage in literature but has received marginal application, particularly when compared to concepts such as socio-ecological resilience. It is argued here that the concept of sustainable resilience requires a more solid foundation in the resilience literature. This approach creates a clear differentiation from reactive conceptualisations of resilience that have a short-term narrow focus. This paper also proposes that cities not only require policies that encourage resilience which is sustainable over time or enduring, but also require policies that themselves are sustainably resilient. The following sections therefore explore policy implications of using this concept and introduce the ongoing research being carried out to develop a sustainable resilience policy framework and assessment tool.

## 2. Research Methodology

This paper presents the early findings from a research project that aims to develop a sustainable resilience policy evaluation and implementation framework. The following sections outline the working concept and draft guiding values or principles resulting from an initial literature review. These are now being tested through a systematic literature review. The detailed methodology and outcomes of this ongoing research will be later published through a journal article.

The initial literature review was based on a thematic analysis of published *personalised* resilience concepts. These are definitions that, although they might be based on mainstream concepts, have been expanded to include a more comprehensive set of characteristics based on a focus on urban/community planning and management. The working hypothesis is that a large portion of these emerging resilience concepts are guided in part by sustainability values, either explicitly or implicitly. In some cases, the authors do not completely outline a new concept but argue for changes in the way resilience is defined in order to become more sustainable over time (see for example Meerow, et al. (2016)). The concept of sustainable resilience has also been used in the literature (see section 3) but has yet to be defined. This paper aims to provide a characterisation of this concept, including a working definition with a focus on urban policy implications.

The inclusion criteria for the thematic literature review is: academic and policy papers and book chapters discussing resilience policy, sustainability thinking, resilience thinking, sustainable resilience, proactive resilience, urban policy for complex problems and multi-actor networks, and climate change policy; papers published in English; and papers published since 1970. This initial literature review included 93 references.

Within the context of this research, policies are understood as the positions taken and articulated by government and other organisations that recognise a problem and state, in general terms, the actions to be taken to address the problem (Dovers, 2005). These are composed of a set of objectives, targets, instruments and agents (Vogel & Henstra, 2015).

## 3. Sustainable Resilience: A Concept to Bring them All and Bind them

The word resilience has existed in the English language for a couple of centuries and has evolved into a number of types of resilience applied to different scopes and used for policy development worldwide (Alexander, 2013). Different resilience concepts have significantly different policy implications. “Bouncing back” or equilibrium-based concepts tend to generate policies that focus solely on recovery and often underestimate the difficulties of managing complex and highly adaptive systems such as cities (Fiksel, 2006; Davoudi, et al., 2012). By focusing only on recovery from and vulnerability to acute unexpected disturbances, such as earthquakes and floods, policies may be limiting the impact of the initiatives they encompass and the long-term resilience of the cities they apply to.



The terms *urban resilience* and *sustainability* are closely related and, in more recent times, increasingly used interchangeably (van der Heijden, 2014). The links between sustainability and resilience have also been highlighted by a number of authors over the last 20 years (Ahern, 2011; Fiksel, 2006; Fiksel, 2003; Perrings, 2006; Arrow, et al., 1995). These however often focus on the use of resilience principles to achieve environmental sustainability.

The term *sustainable resilience*, on the other hand, has been used in some publications (Steiner, et al., 2007; Steiner, et al., 2006; Vogel, et al., 2007; Bonstrom & Corotis, 2012; Afgan & Veziroglu, 2012). There are also a number of publications that advocate integrating sustainability principles with resilience thinking, such as Angeon and Bates (2015). Nevertheless, the concept itself, clearly outlining the characteristics of a type of resilience which is sustainable over time or enduring, has not been fully developed in the literature.

The relatively low uptake and development of this concept may be related to two facts. On the one hand, some proponents see sustainability and resilience as interchangeable concepts voiding the need, in their view, to define a form of resilience which is sustainable. However, although complementary the two terms can lead to significantly different policy outcomes; some sustainability policies may not increase the resilience of cities and some resilience policies may be unsustainable. On the other hand, the term sustainability is often highlighted as ambiguous as well as having charged ethical (Fiksel, 2003) and political undertones (Dovers, 2005). However, we propose that formalising the concept of sustainable resilience which is already emerging can help improve policy development and leverage decades of scientific literature already available. The following sections propose a working concept and guiding values based on sustainability thinking applied to urban resilience policy.

### **3.1 Sustainability as an Approach to Resilience**

Sustainability as an approach can be applied to a number of goals as an overarching guide. It requires taking into consideration the dynamic interactions and behaviours of complex self-organising systems to support coordinated action to address challenges in the context of uncertainty and incomplete information (Ahern, 2011). A sustainability approach also encourages a long-term vision leading to preventive and proactive attitudes. Lederach (1997) for example used the term *sustainable reconciliation* in his book about conflict resolution emphasising that this goal requires a long-term, integrated, inclusive and holistic view of the issues and objectives. The following four overarching values or principles are dominant in the urban sustainability literature and much of the more recent resilience literature.

- Adaptive/dynamic capacity: Although these words may not always be explicitly used, literature about sustainable development and resource management often deals with practices and processes related to adaptation and dynamic systems (Smit & Wandel, 2006; Fiksel, 2006). In this sense, it refers to the capacity of systems to dynamically adapt to changing challenges and opportunities in order to better cope with and manage them (Smit & Wandel, 2006).

- **Sustained/persistent:** At the core of most definitions of sustainability is the ability to sustain human and ecological systems. The way in which this may be done and measured is open for debate, but the ultimate objective is to allow systems to continue to function and persist into the future (Gale & Cordray, 1994).
- **Preventive/proactive:** Another core characteristic of strong sustainability is its focus on long-term futures (which are inherently uncertain) in order to ensure the survival of future generations (Brown, et al., 1987; Dedeurwaerdere, 2014). This is sometimes referred to as the precautionary principle in environmental sustainability management (Dovers, 1995).
- **Holistic/quadruple bottom line:** Sustainability science and policy typically deal with balancing goals of various stakeholders and aiming to identify potential conflicts (Dedeurwaerdere, 2014). The idea of the quadruple bottom line provides a holistic approach where urban sustainability resides in the interaction of four drivers: economic development, social development, environmental protection and effective governance. Within the present context, the latter refers to the institutional capacity of the urban system (Teriman, et al., 2009).

These values have also been highlighted as requirements for long-term sustained resilience. Adger, et al (2011) for example write about resilience highlighting the relationship between adaptive capacity and the confluence of economic development, technology, human capital and governance structures.

### 3.2 Sustainable Resilience Network Values

The above overarching values from sustainability thinking were used to map specific network values that are highlighted in the literature as underpinning forms of resilience which can be sustained in the long term. The following recur throughout this literature.

- **Dynamic:** A complex systems view of cities is required in order to understand and cope with cascading effects of stress events (McIlwain, et al., 2013). Characteristics of complex dynamic systems often mentioned include: non-linearity, uncertainty, emergence (sometimes described in terms of surprise), scale and self-organisation (Berkes, et al., 2003; Damper, 2000). A dynamic view of the urban system emphasises the constant state of flux and change as well as the uncertainty surrounding future stress sources (Folke, et al., 2002).
- **Socio-eco-technical interactions:** The fact that cities can be seen as socio-ecological systems is hardly debated since the rise of socio-ecological resilience. These socio-ecological interactions create the opportunity for technological progress (Folke, et al., 2002). In turn, technology can be used as a tool to enhance the resilience of cities (Fiksel, 2003). Technological progress has also been acknowledged as providing both new challenges and opportunities for urban resilience (Smith & Stirling, 2010). However, information technologies are evolving into socio-technical systems and slowly becoming integral to every aspect of urban asset management and governance. Therefore, sustainably resilient systems also include dynamic technological change and socio-

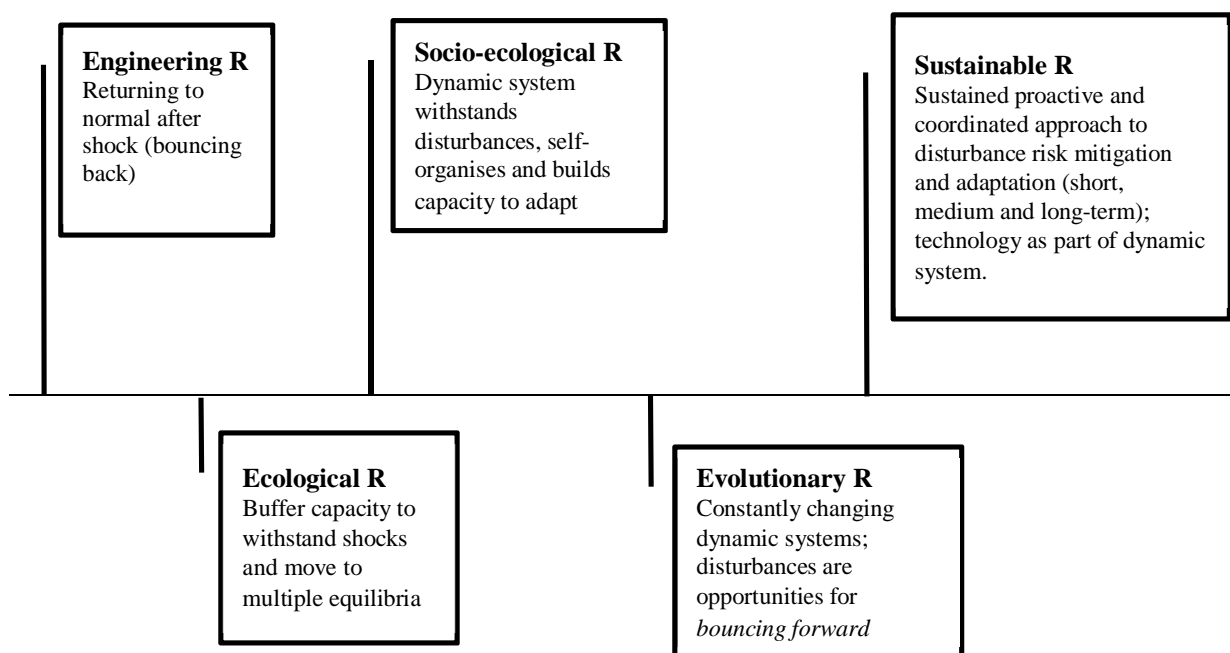
ecological as well as emerging socio-technical system interactions as part of the environmental context.

- Sensitive and adaptive: There is a need to make management and governance systems adaptive and flexible in order to be able to deal with uncertainty. This approach emphasises an ongoing and active learning capacity which is sensitive to feedback from the system components and environment, including the community context (Berkes, et al., 2003; McIlwain, et al., 2013). The Rockefeller Foundation for example talks about reflective and resourceful systems referring to the ability to learn and change behaviours in response to changes (100 Resilient Cities, 2015). Jabareen (2013) further argues that urban resilience in the face of climate change requires uncertainty-oriented planning policies so the system can cope with statistical uncertainty and a continuous range of conditions. Labaka et al. (2015) additionally highlight the need for ongoing data acquisition, monitoring and evaluation in order to maintain the sensitivity of the systems to current conditions.
- Coordinated and cohesive: Cities are formed by systems of networks that function based on their connectivity in order to increase cohesiveness and coordination (Ahern, 2011). Here cohesion refers to the existence of linkages across system components (Fiksel, 2003) and coordination relates to more effective multi-scale network functions (Ahern, 2011). Horizontal and vertical coordination across the components of the systems are necessary for it to function as a whole while maximising its adaptability. This should include feedback loops between and across the components and governance systems (McIlwain, et al., 2013). This for example refers to coordination across infrastructure network governing bodies as well as across political governance levels such as councils and state organisations in order to achieve a cohesive system.
- Capacity to persist: This characteristic is related to having a proactive approach to risk mitigation and abating at different time-scales. It is about reducing the likelihood of stress events occurring and affecting the system in the short, medium and long-term. In the short-term it refers to being able to withstand both acute shock events and chronic stress due to the robustness of the systems, existence of redundancies and flexibility in the face of changing conditions (McIlwain, et al., 2013; 100 Resilient Cities, 2015). In the medium-term it takes in part from evolutionary resilience in that stress events are opportunities to “*bounce forward*”; that is to move away from simple recovery and towards renewal to improve the resilience of the city and the community (McIlwain, et al., 2013). In the long-term is about prevention of future sources of stress, this includes for example climate change mitigation initiatives (Jabareen, 2013). Although having a different understanding of resilience, Register (2014) argues “*if we start thinking in really basic terms, we may realize that the city that is best for adaptation adapts least – because... it doesn’t have to*”. Register also argues against seeking to adapt to changes while ignoring the root cause, principles and likely futures. Truly sustainable resilience policy should address short, medium and long-term time scales.
- Embraces diversity: This relates to the existence of redundancies and promotion of modularisation to spread risk across time, geographic and system scales. This is for example provided by distributed and decentralised systems (Ahern, 2011). Diversity of redundant components means that the system has back-up structures and does not depend

on a single component. Systems are made of sub-systems which are relatively independent of but provide support to and complement each other (McIlwain, et al., 2013). It encourages multiple forms and behaviours in order to create inherent resilience across the whole system (Fiksel, 2003; 2006).

- **Efficient:** It refers to the efficient use of capital and resources through multi-functionality. It supports response diversity within single functions while being able to perform more than one function either simultaneously or progressively (Ahern, 2011). This characteristic can be complementary to diversity where one component can create redundancies by performing multiple functions to maximise the efficiency of the resource investment (Ahern, 2011). It is also closely related to the capacity to persist in that by using resources more efficiently, there is less resources needed and less risk of loss as well as less demand. This can potentially also reduce long-term risks (Fiksel, 2003; Register, 2014). It requires a clear understanding of the system needs, limits and opportunities for synergies across system components.

### 3.3 Sustainable Resilience Concept



*Figure 1 Characteristics of some common concepts compared to Sustainable Resilience*

From the above discussion it follows that dominant concepts of resilience may be insufficient for the development of more comprehensive resilience policy which can be sustained over the long term. The lack of mainstream concepts that openly include sustainability principles may be a result of perception biases, either because authors use the terms interchangeably or because they consider the term “sustainability” too loosely applied, vague or semantically charged (van der Heijden, 2014). Whatever the case, there are good reasons to bring core sustainability aspects to our thinking of resilience in order to improve the effectiveness of urban policy. This is reflected by (although not always explicitly) academics and policy-makers proposing new conceptualisations of resilience that expand the defining characteristics based largely on

sustainability principles. These new conceptualisations may be summarised through the following working definition, referred from here on as urban sustainable resilience:

Urban sustainable resilience is the capacity of socio-eco-technological complex dynamic urban systems to tolerate disturbances, which can be chronic or acute, and persist in a sustained manner through ongoing learning and adapting to changes to the environment and the needs of the system. It requires efficient, diverse, coordinated and cohesive strategies that proactively address short, medium and long-term challenges. Urban sustainable resilience is underpinned by sustainability and dynamic system resilience principles in order to define practical policy aspects that allow cities to tolerate disturbances, evolve with the changing environment (where environment refers to climate, social sentiment and technological context) and mitigate future sources of stress.

Figure 1 briefly outlines some of the different policy implications for some more common resilience concepts and the proposed sustainable resilience concept.

## 4. Urban Sustainably Resilient Policy Qualities

*“Urban policies are critical in making cities more resilient and are crucial factors in bringing the governance of global environmental problems to urban contexts”* (Jabareen, 2013). However, from an offer and demand point of view, policy-makers struggle to offer policies that address long-term resilience challenges and citizens often do not provide a sustained demand for policy interventions. This is in part due to the short election cycles and people often failing to understand the urgency of having a long-term vision. This leads policy-makers to take advantage of windows of opportunity when disaster strikes to introduce resilience policies (Vogel & Henstra, 2015). The constantly changing political, economic and social environment also prompts short-term interventions rather than sustained action (Broniatowski & Weigel, 2008). However, resilience as conceived here, requires continual action incompatible with constantly changing policies. In addition to urban policies’ goals, targets, instruments and agents striving to create more sustainably resilient urban systems, it is therefore hypothesised that the policies themselves can have sustainable resilience qualities in order to ensure sustained outcomes. Under this hypothesis policies themselves should show the seven values outlined in the previous section. After exploring the implications of this proposition (to be published at a later date), the following policy qualities are suggested to form the policy development guiding principles.

- **Political resilience:** The political environment has a clear impact on the choice of policies and the time-scale of their objectives and implementation. Short-term political cycles commonly translate into short-term goals and policies but to achieve sustainable resilience of urban systems a long-term strategy is also required. *“A system designed under these circumstances must be able to deliver value under a constantly shifting political environment... These systems must therefore have an architecture that allows for political sustainability”* (Broniatowski & Weigel, 2008). Political resilience means that policies need to be designed to withstand changes in government within and across levels of governance. This is closely related to policy goals, values and interests, and although it depends on the perception of delivered value, this is not a sufficient condition

(Broniatowski & Weigel, 2008). Multi-level governance perspectives can leverage on opportunities and identify contradictions that arise from the interpretation of challenges that apply to different scales and spheres of governance and authority (Bulkeley & Betsill, 2005). Promoting a resilience-based culture across stakeholder groups can also help improve coordination and communication, and lead to more politically resilient policies (Labaka, et al., 2015). Political resilience also relates to the way issues are framed and perceived by policy-makers (Vogel & Henstra, 2015). Sustainable resilience policies should be framed in such a way that urgency that springs to action is conveyed without politicising the issues. This can help reduce the risk of changes in the government's political views affecting the objective assessment of policy outcomes. In the long-term, policy-makers should aim to integrate successful aspects of implemented policies into the overarching values that guide the evaluation and implementation of subsequent policies and laws; including across other policy fields. *“To be robust and durable over time, adaptation principles and objectives must be integrated into day-to-day planning and decision-making processes”* (Vogel & Henstra, 2015).

- Economic resilience: Political will, the collective willingness to do something, is critical to successful policy implementation but may waver depending on a number of aspects (Vogel & Henstra, 2015). Funding of any policy is commonly closely tied to political will. This often leads to funding short-term programs with ribbon-cutting opportunities at the expense of long-term cost (Herrmann, et al., 2009). Setting resilience priority areas and cost-benefit analysis can help deal with limited funding for capital investment. However, designing policies that encourage infrastructure that has more than one function while increasing urban resilience and providing potential financial gains can support political resilience by providing economic resilience (McIlwain, et al., 2013). Policies should take into account the financial sustainability of the initiatives but also be able to absorb additional cost brought by evolving challenges as they arise (Labaka, et al., 2015). Economic resilience could entitle transforming sunk costs into returns on investment (ROI) by leveraging inter-governance synergies (e.g. integrating urban waste treatment, district heating/cooling and industrial waste heat disposal). Assessing commercial co-benefits and partnering with industry for long-term financing of resilience initiatives as well as coordinating budgets across governance boundaries can also help achieve this (McIlwain, et al., 2013).
- Social resilience: Stakeholder support commonly influences policy choices and actively addressing stakeholder concerns can help avoid implementation failure (Vogel & Henstra, 2015). Resilience policies should include *“adaptable social infrastructure to assure meaningful participation”* (Ahern, 2011) in order to maintain sensitivity to the constantly changing needs and interests of the system. Additionally, for policy to be sustainably resilient in the face of constant change it is suggested that it needs to be able to steer or adapt to changes in social sentiment (general priorities and views of the local public). Achieving this may require integrating deliberative democracy processes which have been proposed as a way of delivering long-term transformational policy objectives (Hartz-Karp, et al., 2013). Progress towards higher levels of resilience often also requires social uptake of new behaviours (McIlwain, et al., 2013). Long-term policy effectiveness and social support requires active engagement with stakeholders and brokering

knowledge in a way that the community can be receptive to it. This could mean integrating educational programs or gaining insight into how decisions are made by individuals in order to frame policy actions appropriately (Shediac-Rizkallah & Bone, 1998). The growing fields of opinion mining and sentiment analysis may also be of use (Pang & Lee, 2008).

- Environmental or contextual resilience: A network value of sustainably resilient systems is proposed to be that their environment is formed by its socio-ecological components as well as by technology. The latter is often a key part of urban resilience policy actions and frequently changes at a higher pace than the built environment and models used to design the policy in the first place (McIlwain, et al., 2013). Action plans and strategies resulting from resilience policy need to be able to remain sensitive and adapt to changes in the ecological and technological environment in order to stay effective over time. The understanding of the policy priorities and what forms, for example, critical infrastructure may also change over time (McIlwain, et al., 2013). This means that resilience policy programs should include active learning and monitoring processes that encourage frequent and comprehensive reviews of the needs and opportunities provided by the changing environment.

## 5. Future Research

This work is part of a three-year project. Future research will continue a systematic literature review of academic and government documents related to urban resilience and policy. This effort will meticulously map the characteristics of emerging concepts of urban resilience which are framed as more sustainable over time; following sustainability principles explicitly or implicitly. This will be used to complete the working concept and draft framework which will be tested through expert consultation that includes academic, government and industry professionals. The revised version will be further developed into an evaluation framework consisting of specific indicators for urban sustainable resilience policy assessment. This will be tested through a series of international case studies that will also include policy content and processes analyses. This research will aim to deliver three main practical outcomes: (i) best practices based on success factors of sustainable resilience policy from international case studies; (ii) a set of comparators/indicators that allow evaluating these types of policies across city and state borders; and (iii) a practical tool for policy-makers for evaluation and implementation of more effective and sustainable urban resilience policies.

## 6. Conclusions

This publication briefly explores the relationship between resilience concepts and urban policy as well as suggest a working concept for the term *sustainable resilience*. This is done by drawing from emerging resilience concepts which are implicitly or explicitly driven by sustainability principles. The authors also introduce a set of urban sustainable resilience values and policy principles. Future research will continue a systematic literature review to increase the robustness of the proposed concept and framework as well as continue developing them. The resulting framework will be tested and validated through further research.

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# CIB Smart City Road Map and Vision

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## Abstract

Urbanization had been rapid, currently 54% of the global population lives in cities and it is projected to rise to 70% by 2050. New cities have emerged, and hundreds are expected to be built in coming years. Cities are also engines of economic growth, accounting for 80 % of the global GDP (UN habitat 2015). But they also consume around 75 % of global primary energy and responsible for 70 % of the global greenhouse gas (GHG) emissions (UN Habitat 2015, EIP SCC). All sectors associated with urbanization (transport, building construction and maintenance, housing, waste management, energy, etc.) are registering trends that raise sustainability issues.

Urbanization trends pose a need for strategic and innovative approaches to urban design, planning, management and governance. The accompanying trends in technologies play a significant role in 21st Century urbanization as technologies are increasingly supporting business functions, city logistics and grids, transport, delivery of basic services, environmental management systems, government operations, data-driven industries like finance, and people-to-people interactions.

CIB Task Group 88 has created smart city roadmap where the main findings were following. Technologies have a crucial role and potential in address the urban challenges, presenting new opportunities and smart approaches for the global community to make cities inclusive, safe, resilient, and sustainable.

Due to climate change and lack of critical resources energy management and technologies to transform our cities low carbon becomes important. Digitalisation and new technologies enables us to use more and more data in real time. In addition internet of things makes it possible to use, combine and enrich data from many different sources. The future city actors and stakeholders are changing internet of things to internet of meaningful information. New technologies enable also service based solutions. Future construction business is in transformation. Construction will change to services: living as a service, energy as a service, urban environment as a service. Future smart cities are sustainable and resilient and they are constructed from self-healing materials and systems. Zero carbon resource efficient solutions are created without compromising peoples' well-being.

**Keywords:** smart city, sustainability, energy, buildings, urban planning, traffic

# 1. Introduction

All around the world, urbanization is a growing trend. As more and more people get together, smart systems and their integration need to be developed, not only to provide the services that people need but also to do so efficiently with minimum impact on the environment. It can be said that efficient ICT, one part of which is the Internet of Things, is a common dominator: tying together services, residency, mobility, infrastructure and energy. It is a global challenge to reduce environmental impact and the carbon footprint.

At the same time, societal development needs to be addressed and the focus put on people's well-being. Pressure is growing to reduce our environmental impact, and there is a parallel compelling need for business to remain globally competitive. Sustainable transformation of cities is only possible when it is done in a smart way. Smart city design, operation and management need to be done at system level. Sub-optimization of individual components will not lead to optimal performance of the system. Multi-target optimization is not an easy task, but it becomes necessary as different components and systems are interlinked and interconnected – irrespective of where they are physically located. Traditional sector-based industries and value chains are also changing, and completely new business models are starting to emerge. Radical innovations and paradigm shifts are changing our whole city systems.

Cities are a driving force in generating world's economic growth. Cities are becoming even more important as urban population and populated areas grow leading to a rapid increase in resource consumption and emissions. The principal challenges for cities, around the globe, are to deliver better services while being globally competitive, and meeting climate targets. Expenditures on improving energy efficiency, modernizing infrastructure and on creating high quality living and working environments are enormous. At the same time, cities have limited and less financial and resources for governance and services.

Innovation in the form of 'smart city solutions' can deliver technologies, products and services that meet the dual challenges of reducing greenhouse gas emissions and delivering more efficient services. Cities worldwide are modernising and becoming poles of competitive strength. There is a clear need for resilient, sustainable, safe, energy efficient, connected, good quality to live and work in cities.

The rapid development of information technology, technologies for local small-scale energy production, as well as the transport solutions are the key enablers for cities becoming more resource efficient although at the same time meeting the users' needs better. The built environment, i.e. buildings and transport and utility networks, cannot remain only a passive platform. It also needs to be reshaped to make optimum use of the technology opportunities.

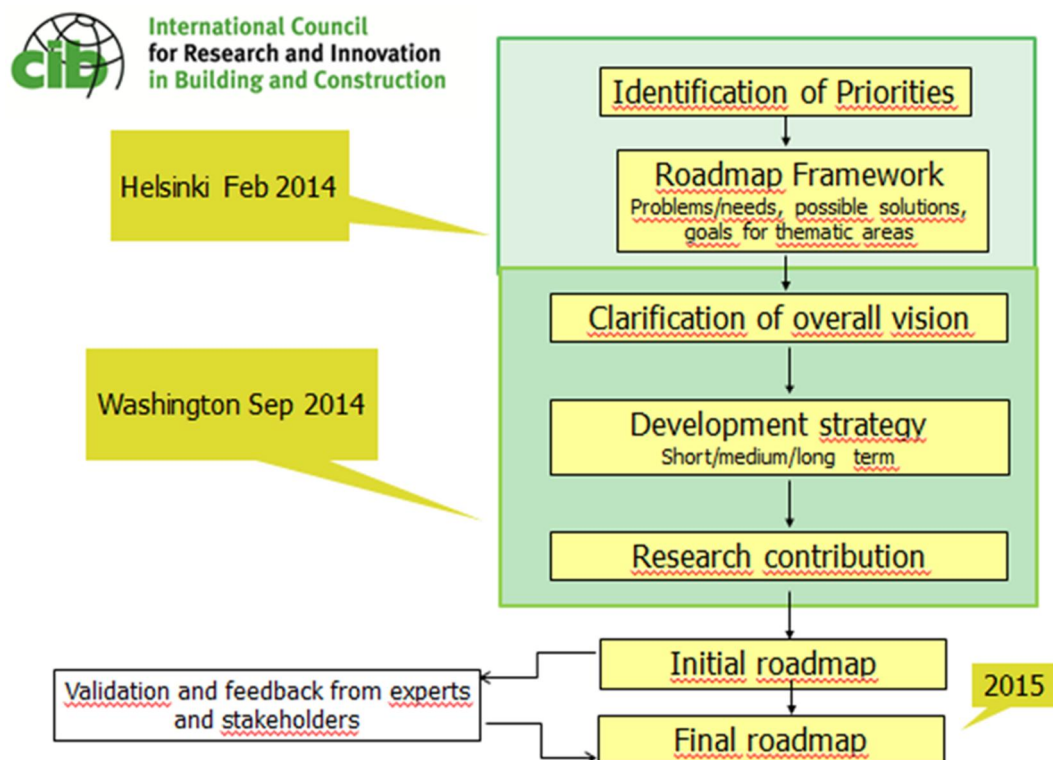
The aim of this work was to compile the CIB community's vision and perspectives on the future of cities under the impact of the expected development of the new technologies (distributed energy, virtual services, urban transport and living/working opportunities). In addition this task group created strategic roadmap for the building and construction related research needed for

envisioned future smart cities. The challenges and contributions were identified from the political, social, market, environmental and technological perspectives but also the values and their effect on different perspectives were considered in the workshops.

## 2. Methodology

The roadmap work started with the conceptual framework, how we define smart city in the CIB context and what aspects are included in our frame. After framing the CIB context in smart cities the state-of-the art was defines and the identification of priorities and priority themes were defined. Highlighting today's state-of-the-art it was logical to set the vision how we want to see a smart city in the future. Setting the vision sets also the requirements for development strategy and research as well as industry needs to realise the vision.

The first task group meeting and workshop were organised in Finland on February 2014. The workshop had 15 participants among the 22 task group members. The second meeting was organised as a webinar in June 2014 and the third workshop meeting was held in Washington on September 2014. The initial roadmap was send to feedback and validation for the CIB community as well as for expert and stakeholder consultation. The interactive work process and schedule are shown in Figure 1 below.



*Figure 1: The interactive work process and schedule of the CIB smart city roadmap*

### 3. Main priority areas and the CIB vision

The priority areas for the smart city roadmap were identified in the first workshop. The participants listed and discussed in three groups about choosing the priority areas. The main themes identified from the prioritisation of topics were structured into following groups:

- **Energy:** increasing the use of renewable energy, optimisation of the energy system and the management and balancing of energy supply and demand.
- **Existing and new buildings:** new solutions for renovation, living comfort and replication of building services and solutions.
- **Land use, infrastructure and asset management:** adaptive use and integration to existing systems.
- **Transport and mobility:** Easy and fast mobility, smart management systems, reducing the need and time for travelling.
- **Communities and users:** people participation, on-demand services, increasing awareness, trust and security, and good well-being.

The discussion included many cross-cutting themes, which are relevant for all priority areas. ICT solutions, interoperability and integrated planning and systems are essential elements in the smart city context. The discussion also strongly reflected cities' sustainability targets, including economic, environmental and social aspects. Especially efficient resources use and low carbon targets were considered as priority targets. One of the major changes considered was the development towards service based economy. In addition, cities adaptability and resilience was highlighted, as well as policy and governance related issues with improved collaboration and communication.

In CIB smart city workshops each theme group analysed the needs/problems from the perspectives of policy, markets, products & services and technologies. In addition each group already started to draft reasons and solutions for possible problems. In the end of that session a vision/goal for desired state was written. The group work result tables are presented below.

Commonly the tables highlight the need for technologies and services to support sustainability in cities and also the importance of technologies to support sustainable choices in people everyday life; i.e. making the sustainable choice the most convenient and easy choice without compromising well-being. The visions also highlight the new technologies for predictive, resilient and self-sustaining energy and resource management. In addition the vision states the transformation from internet of thing to internet of meaning, highlighting the importance to enrich the data to decision making to support city goals.

The detailed roadmaps for each theme can be read from CIB roadmap publication.

### Analysis Framework: Energy & Buildings

	Problem or need	Reason for problem	Possible solutions	Vision (Goal)
Policies	<ul style="list-style-type: none"> <li>• Distributed generation and its limits</li> <li>• Reliance on single energy source (fossil / centralised)</li> </ul>	<ul style="list-style-type: none"> <li>• Lack of awareness</li> <li>• Legacy of design: central production</li> </ul>	<ul style="list-style-type: none"> <li>• Microgrids &amp; islanding</li> <li>• Load balancing</li> <li>• Transactive energy: market &amp; technology</li> </ul>	<ul style="list-style-type: none"> <li>• Clean, efficient and sustainable energy sources</li> <li>• Nearly zero energy buildings</li> </ul>
Markets	<ul style="list-style-type: none"> <li>• Reusing waste heat</li> <li>• Primary energy vs. delivered energy (process losses)</li> </ul>	<ul style="list-style-type: none"> <li>• Uncertainty</li> <li>• Lack of ROI for environmental protection</li> <li>• Variable discount rate &amp; time value for money</li> <li>• Costs &amp; pay back time</li> </ul>	<ul style="list-style-type: none"> <li>• Size-based sliding scale pricing &amp; taxation</li> </ul>	<ul style="list-style-type: none"> <li>• Pricing policy that provides ROI on resilience, environment etc.</li> <li>• Dynamic energy pricing</li> </ul>
Products or services	<ul style="list-style-type: none"> <li>• Building stock inertia</li> <li>• Design to change user behaviour</li> <li>• Energy efficiency &amp; losses</li> </ul>	<ul style="list-style-type: none"> <li>• Renovation need is huge</li> </ul>	<ul style="list-style-type: none"> <li>• Grid monitoring</li> <li>• Adaptive building management</li> <li>• User education</li> <li>• Real time feedback &amp; pricing</li> </ul>	<ul style="list-style-type: none"> <li>• Smart grid &amp; city</li> <li>• Adaptable and flexible structure design</li> </ul>
Technologies	<ul style="list-style-type: none"> <li>• Resilience</li> <li>• Accessibility and affordability</li> </ul>	<ul style="list-style-type: none"> <li>• Lack of ROI for resilience</li> <li>• Fluctuating supply from RES</li> </ul>	<ul style="list-style-type: none"> <li>• Response market &amp; mechanisms</li> </ul>	<ul style="list-style-type: none"> <li>• Holistic design</li> <li>• Novel building materials</li> <li>• Different design levels: Horizontal, vertical, temporal, 3D etc.</li> </ul>

Figure 2: Energy and buildings theme and its vision

### Analysis Framework: 1) Infrastructure and asset management, and 2) Resources and waste

	Need	Reason for problem	Vision (Goal)
Policies	<ul style="list-style-type: none"> <li>• Transition to sustainable energy &amp; resource efficiency</li> </ul>		<ul style="list-style-type: none"> <li>• Self-managing multi-functional infrastructure for resource efficiency and zero waste.</li> </ul>
Markets	<ul style="list-style-type: none"> <li>• Reduce life cycle costs</li> <li>• Building stock management</li> </ul>	<ul style="list-style-type: none"> <li>• Legacy of infrastructure and investment</li> </ul>	<ul style="list-style-type: none"> <li>• Smart energy management for water, waste and energy management / and smart technology</li> </ul>
Products or services	<ul style="list-style-type: none"> <li>• Adaptive infrastructures</li> <li>• Integration of existing infrastructure with new infra</li> </ul>	<ul style="list-style-type: none"> <li>• Clean water scarcity</li> </ul>	<ul style="list-style-type: none"> <li>• Effective urban water and waste water management</li> </ul>
Technologies		70	<ul style="list-style-type: none"> <li>• Effective waste &amp; resource management</li> <li>• Zero waste</li> </ul>

Figure 3: Land use, infrastructure and asset management theme and its vision

### Analysis Framework: Transport & Land Use (T & LU)

	Problem or need	Reason for problem	Possible solutions
Policies	<ul style="list-style-type: none"> <li>Too much land use for transport and infrastructure (parking lots)</li> </ul>	<ul style="list-style-type: none"> <li>Locations not optimally planned</li> </ul>	<ul style="list-style-type: none"> <li>Better management coordination: Municipal to regional level</li> <li>Better means for public participation in development process</li> </ul>
Markets	<ul style="list-style-type: none"> <li>Cities develop too quickly</li> <li>Population dissatisfaction with land use</li> </ul>	<ul style="list-style-type: none"> <li>Opportunities for work are more intensive in cities -&gt; Urbanisation</li> <li>Values (interests) of populations are changing faster than development</li> </ul>	
Products or services	<ul style="list-style-type: none"> <li>Slow development and changes in T &amp; LU</li> <li>Energy demanding solutions</li> <li>Too much time</li> </ul>	<ul style="list-style-type: none"> <li>Capital intensive development, different hinders e.g. legality and public acceptance</li> <li>Lack of public transportation and un-motorized options</li> </ul>	<ul style="list-style-type: none"> <li>Intelligent Transport System</li> <li>Retrofitting current systems to become more energy efficient and fuel consuming + ITS</li> </ul>
Technologies	<ul style="list-style-type: none"> <li>Optimal regional layout is not yet understood/explored</li> </ul>	<ul style="list-style-type: none"> <li>Non-multidisciplinary research and collaboration -&gt; suboptimisation</li> </ul>	<ul style="list-style-type: none"> <li>Support for- and initiatives towards multidisciplinary research and collaborations</li> </ul>

Figure 4: Transport and land use theme and its vision

### Analysis Framework: Community & users

	Problem or need	Reason for problem	Possible solutions	Vision (Goal)
Policies	Healthy & happy citizens	<ul style="list-style-type: none"> <li>Lack of power/involvement in decision making</li> <li>Land use (crime &amp; security)</li> </ul>	<ul style="list-style-type: none"> <li>Open communication &amp; governance</li> <li>Creative consideration in urban planning</li> <li>Decision making to local level</li> </ul>	<ul style="list-style-type: none"> <li>Health &amp; wellbeing</li> <li>Inclusive + equal + feeling part of the society</li> </ul>
Markets	Set the standards <ul style="list-style-type: none"> <li>Data security</li> <li>Interfaces</li> <li>Requirements</li> </ul>	<ul style="list-style-type: none"> <li>Lack of jobs</li> </ul>	<ul style="list-style-type: none"> <li>Mapping of human resources</li> <li>Distributed facilities</li> </ul>	
Products or services	Citizen engagement  Affordability of housing	<ul style="list-style-type: none"> <li>Lack of education &amp; career opportunities</li> <li>Affordability of adequate healthcare</li> </ul>	<ul style="list-style-type: none"> <li>Self monitoring -&gt; Preventive health care</li> <li>Service resilience</li> <li>Better control on services</li> </ul>	
Technologies		<ul style="list-style-type: none"> <li>Lack of good quality buildings/homes</li> </ul>	<ul style="list-style-type: none"> <li>Warning systems/ predictive monitoring of vulnerable people</li> <li>Interactive infrastructure</li> </ul>	



*Figure 5: Community and users*

## **4. Trends, drivers and vision of the business environment**

Cities are facing serious challenges stemming from global megatrends:

- Urban growth and urban sprawl: urban populations are estimated to grow by 2,3 billion over the next 40 years. Immigration causes problems in many parts of the world.
- Ageing population: the number of people over the age of 60 is expected to triple by 2050. This sets concerns of sufficient workforce.
- Global warming: cities consume 75% of world's energy and produce 80% of its GHG emissions.

Under these circumstances, cities are forced to adapt and improve the whole city system and its efficiency, for example develop new energy systems and tackle social issues. The philosophy of smart cities is to see challenges as opportunities and take advantage of other trends, such as

- Digitalization: the proportion of broadband access has exploded worldwide which enables more efficient and economical service provision and internet and remote retail and services.
- Automation and servitization: more and more jobs are carried out by machines and the trend has been since a long time from goods based manufacturing economy to service and solution oriented economy.
- Technological development: e.g. intelligent transport (automatic vehicles, electric cars) and smart grids give new opportunities for cities to think about their service provision."

On the positive side, also 85% of innovations happen in cities. Cities are driving forces in generating economic growth. Innovation in the form of "smart city solutions" can deliver technologies, products and services that meet the dual challenges of reducing greenhouse gas emissions and delivering more efficient services.

A key goal for many cities that want to be smart is to achieve better transparency in decision making through involvement and engagement of citizens in decision making by participative and co-creative approaches, providing data publicly (open data) and providing opportunities for bottom-up initiatives.

## **5. Barriers**

There exists various barriers that can impede or restrain the realisation of the development steps proposed in this roadmap. They are into following four categories: administrative

and legal barriers, technical and infrastructural barriers, economic and market barriers and social acceptance and political barriers.

One of the most challenging ones is that cities have limited and often reducing financial resources for providing governance and various services. Often it is hard to understand the real benefits and costs of investments, and evaluate their life cycle impacts in the long term. Other common barriers for many smart city developments are related to systems sub-optimisation and unclear vision. It is typical that there are many stakeholders involved from different sectors and backgrounds, which makes the integration of processes and systems complex, and communication and collaboration need lots of efforts. Another common barrier is that the relationship between data monitoring and services and the privacy and security of users' data is not clearly regulated. **Error! Reference source not found.** below summarises some of the main barriers for the main targeted development areas and main cross-cutting themes in this roadmap.

*Table 1 Summary of main barriers for the targeted roadmap development areas and cross cutting themes.*

Barriers	Administrative and legal barriers	Technical and structural barriers	Economic and market barriers	Social acceptance and political
<b>Energy</b>	Legal issues and lacking of new business models for local energy services and supply/demand matching.  Development and changes are slow.  Sub-optimisation.	Lots of actors makes interoperability and integration of processes and systems is complex.  Limits of distributed energy (e.g. timing and fluctuation).  Location affects to the accessibility and availability of RES.	High costs and long pay-pack times.  Costs and efficiency still developing for some supply technologies, e.g. PV.	Legacy of design for central energy supply. Lack of common vision.
<b>Existing and new buildings</b>	No common semantics or standardisation for communication and data exchange.	Isolated sensor networks and subsystems  Rare integration of smart products, services and technologies into wider city systems and tools.	Doubts about ROI for investments.  Smart renovation solutions not cost-efficient and focus on isolated buildings	Lack of awareness  Different interests of stakeholders (landlords, tenants, investors, owners, ..)

	<p>Lack of policies for the integration of smart renovation measures</p> <p>Data monitoring vs services vs privacy is not clear regulated</p>	<p>Huge renovation need. Maintenance reactive.</p>	<p>rather than district integration.</p> <p>Building stock inertia.</p>	<p>Old habits.</p>
<b>Infrastructure</b>	<p>Sectorial approach; separate standards &amp; policies for various infrastructure assets</p> <p>Maintenance and renovation sub-optimised.</p> <p>Path dependence in existing infrastructure</p>		<p>Long term investments vs. short term costs.</p> <p>Fiscal problems</p>	<p>Lack of asset management expertise</p> <p>State of stagnation without developing attitude</p>
<b>Mobility</b>	<p>Too much land use for transport and infrastructure (e.g. parking lots).</p> <p>Unnecessary trips.</p>	<p>Lack of public transportation and un-motorized options.</p> <p>Rarely linked to other city services.</p>	<p>Many cities develop uncontrollable.</p>	<p>Mistrust towards reliability of public transport.</p>
<b>Communities and users: citizens</b>	<p>Lack of possibility for involvement in decision making. Lack of information.</p>	<p>Security and privacy of data.</p> <p>Services, systems and interfaces that are not easy to use.</p>	<p>Affordability of housing.</p> <p>Lack of education and career opportunities.</p>	<p>Users resistance and mistrust towards new solutions.</p>
<b>Governance, policies, and land use</b>	<p>City decision making in silos. Development and changes are slow.</p>	<p>Sub-optimisation of the land-use.</p> <p>Inadequate evaluation of life cycle criteria.</p>	<p>Hard to see the impacts of the investment costs in the long term.</p>	<p>Dissatisfaction of people regarding the land use.</p>
<b>Interoperability and ICT</b>	<p>Data monitoring vs services vs privacy is not clear regulated</p>	<p>No common semantics and standardisation for communication and data exchange.</p>	<p>Hard to calculate the benefits of investments.</p>	<p>Inadequate collaboration, communication and integrated planning.</p>

		Lack of open data.		
<b>Resource management; environment</b>	Sub-optimisation.	Clean water scarcity.	Lack of ROI for environmental protection.	Competition for resources.

## 6. Discussion and Conclusions

The global challenge is to reduce environmental impact and carbon footprint. At the same time societal development needs to be addressed and people well-being must be in focus. Pressure is growing to reduce our environmental impact and there is a parallel compelling need for business to stay globally competitive. Investment and expenditure needs for improving energy efficiency, modernizing infrastructure and creating high quality living environments are enormous. At the same time, cities have limited access to financial resources.

Globalisation has opened new markets and is requiring much more competitiveness from local industries. The advanced and modern systems deliver new services and opportunities to growing well-being. But at the same, societies have become more vulnerable to human based criminality and also to natural based catastrophes. Climate change is feeding new and unexpected phenomena requiring more robust but flexible and self-recovering systems.

The concrete threats to the urban system include natural disasters and other sudden shocks (storms, terrorism, collapse of vital technical infrastructure), vast consequences of climate change (decreasing biodiversity in the ecosystems , repeated flooding, long periods of hot and arid summer seasons, distorted population structure, escalating migratory movements, and epidemic diseases). These challenges are very different from each other as some occur suddenly (epidemics) and have relatively limited duration (collapsed infrastructure) while some affect the society slowly and may be very difficult to change or to adapt to.

Smart cities emphasize the relations between the urban flows on energy, material and people as well as governance and human behaviour. Further, the relations need to be explored in a holistic way realise cities of high resiliency and sustainability. Innovation in the form of 'smart city solutions' can deliver technologies, products and services that meet the dual challenges of reducing greenhouse gas emissions and delivering more efficient public services. Cities worldwide are modernising and becoming poles of competitive strength.

If we think about the concept of a smart city, we can easily conclude that currently the deployment of technologies and ICT solutions for energy use and production, mobility and transport is still fragmented, limited in scale and thus with low impact. A European large scale action is needed to bring the many valuable results of research and development projects together, and to focus on deployment. This can be done only by accelerating full-scale deployment of technological smart city solutions in the key areas of energy production, distribution and use, as well as in mobility

and transport. ICT is the key enabler for the smart city solutions and new technologies creating interdisciplinary opportunities.

Vitality and capacity for reinvention form an essential part of a Smart City. This means that the building stock and infrastructure must be flexible according to changes in the usage needs as well as the users. A Smart City also attracts new residents, and it must be able to grow sustainably. Eco-efficiency involves recycling districts and buildings to new uses. Energy efficiency involves reducing the energy consumption of old buildings so that the energy demand of new buildings can be satisfied with the saved energy. In addition other aspects of sustainability like social and economic aspects must be taken into account.

Choices made concerning a single building have only a limited impact. The impact can be scaled up, if the choices are made on the district level, instead. In district-level projects, it is possible to invest in innovations, product development and structural changes. With regard to energy efficiency, for example, district-level improvements and new construction solutions can achieve greater benefits than if they were implemented one building at a time.

Unlike in traditional building stock and other infrastructure, interactive data transfer is an essential part of Smart buildings. Advanced technology and economy are not enough to make a building smart. At its best, a building could promote the well-being of its residents or the people working there. At its simplest, the high quality and healthiness of the indoor air can be ensured. Taken further, the building can, for instance, monitor the condition and safety of senior citizens. At the district level, the quality of life of, for example, people with memory disorders could be improved by allowing them a wider living environment through new technology.

Modelling is an absolutely necessary tool, as the initial data produced with it can be utilised in the simulation of functionality and solutions affecting energy efficiency. Modelling produces compatible data so that a common model of the district's building stock can be generated as part of the city model.

If the development project concerns an entirely new district, the infrastructure models and building construction models can be reasonably easily combined even today. This can be done at many different levels. At its simplest, it is a question of visualising the planning options. At its most demanding, the operations and traffic flows planned for the district are included, and the best solution for the overall system selected. The task becomes somewhat more laborious, if old building stock or old infrastructure is involved. Model-compatible data of these must be obtained by means of, for example, laser scanning and ground penetrating radars, if the original plans are not available. Complete modelling of the district is necessary when the objective is a comprehensive city model.

Digitalisation and new technologies enables us to use more and more data in real time. In addition internet of things makes it possible to use, combine and enrich data from many different sources. The future city actors and stakeholders are changing internet of things to internet of meaningful information. New technologies enable also service based solutions. Future construction business

is in transformation. Today's construction of buildings and roads will change to service business like living as a service, energy as a service, X- as a service.

Future smart cities are sustainable and resilient and they are constructed from self-healing materials and systems. Zero carbon resource efficient solutions are created without compromising people's well-being.

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# **Political frame conditions for energy efficiency: context sensitivity, energy flexibility and the question of scale**

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## **Abstract**

This paper is intended to highlight some of the challenges of regulating integrated energy solutions in buildings, and so provide a better basis for both regulation and initiating innovation processes related to energy efficiency. The paper is based on a mapping of regulatory and incentive schemes and two extended case studies consisting of in depth interviews, a survey, document studies and field visits.

The paper discusses political frame conditions that are intended to promote energy efficient solutions in Norway's building stock. The starting point is that although such solutions are both feasible and financially rewarding, the practical outcomes seem to be limited. In order to understand why, we analyse the nature of current regulative instruments and two different cases of energy efficiency innovation processes by the dimensions of scale and context sensitivity. The main finding is that the very nature of projects successful in integrating heterogeneous actors, are context sensitive and small-scale. Efforts in constructing regulation schemes in order to scaling up such successful solutions are problematic due to the nature of those regulatory schemes – relying on standardisation and the measurement of distinct legal entities. If we want to move real-world energy optimization from small to large scale, one should formulate regulatory measures in such a way that they combine standardized with the development of individualized and tailored solutions.

**Keywords:** Energy efficiency, regulation, standardization and context

# 1. Introduction

Buildings account for more than 40% of global energy use in both developed and developing countries (UNEP 2009), and calculations from e.g. The Norwegian Agency for Energy Savings (ENOVA), show that there is a significant energy efficiency potential by integrating buildings' energy systems (ENOVA 2012). Although the explicit political goal is to optimize buildings' energy efficiency, the current political instruments in Norway are such that this goal is not always supported– and sometimes the policy instruments even function as an obstruction.

Many propose increased interconnection of buildings energy systems as a key response to stricter requirements for the buildings' energy and environmental performance. New technological solutions and pilot projects for low-energy and energy positive buildings have shown the feasibility of such a response. Such solutions, however, require flexibility in providing the energy needed for the operation of buildings – from grid systems (electricity and thermal) as well as from the building itself (e.g. building-based PV, wind turbines, geo-thermal, heat pump systems, bio-based CHP etc.).

Summarized, given the importance the energy demand represents, and the unexploited potential, ENOVA argues that many energy efficiency projects *should* have been implemented, and still, they are not. There is thus a *perceived* paradox in the fact that there are available solutions that are both technically feasible and financially rewarding, but are not actually realized in the market. In this paper, we argue that many preconditions, other than pure techno-economic, are important when seeking to realize energy flexible solutions for buildings.

Energy flexibility may be defined as facilitating for changing sources of energy, e.g. not locking buildings to one source only. Such flexibility is crucial in order to facilitate more renewable energy to be incorporated into energy consumption, and furthermore to match calculated potential for energy consumption with the actual energy consumption (EBC, 2014). Hence, energy flexibility in its broader sense also includes more interaction and flexibility both internally within a building, using e.g. short-term and long-term thermal storage, and interaction between buildings and/or buildings and external energy systems.

In this paper we highlight how the nature of policy instruments makes certain types of systems and systemic changes such as energy flexibility problematic. We combine an assessment of the societal and political driving forces with empirical studies of one small-scale and one large-scale case of energy efficiency innovation. By this we aim at contributing to the identification of more robust policy measures for increased energy flexibility and interaction between buildings and the energy system at multiple levels. We thereby also aim at highlighting the importance of addressing the political feasibility of the proposed measures, which may also include more shared visions and understandings across traditionally separated policy sectors.

The first case is a small-scale energy entrepreneurial project that integrates and utilizes both heat flows and CO<sub>2</sub> outlets between companies in a food industry cluster. This case shows a very successful project in terms of energy optimizing, it takes in to account and exploit the specific



contextual conditions. At the same time – as this is a context specific solution – it may not be optimal as a large scale solution for all other such clusters.

The second case is a large scale state initiated program which has lead to a significant change in the building market. This is the so called *passive house program*. The standards and means of both regulating and registering this initiative are of such a nature that it is easy for large scale adoption. But these are not context sensitive standards, and as such the solutions are not optimal for the specific sociotechnical situations.

One important observation is that the specific small scale initiatives, such as in case 1, are demonstrably successful in saving energy, while the specific houses in large scale initiatives varies a lot in such performance. At the same time – the large scale initiative has a lot more impact in the over all energy savings. We would therefore argue that if we want to move energy optimization from small to large-scale, regulatory measures should function in such a way that they combine standardized solutions with development of individualized and tailored solutions where appropriate.

## **2. Background – Policy framework for more energy flexible buildings**

Policy instruments may be divided into three categories; regulatory, economic and informative. Regulatory instruments are *“undertaken by governmental units to influence people by means of formulated rules and directives which mandate receivers to act in accordance with what is ordered in these rules and directives”* (Bemelmans-Videc, Rist & Vedung, 1998, p. 31). Economic policy instruments involve either *“... the handing out or the taking away of material resources, be they in cash or in kind. Economic instruments make it cheaper or more expensive in terms of money, time, effort, and other valuables to pursue certain actions.”* (Bemelmans-Videc et al., 1998, p. 32). Economic instruments may comprise discount campaigns, tax credits, funding, loans and grants in various forms that can be targeted at different areas, different populations, etc. Informative instruments, or “moral persuasion”, cover “attempts to influence people through the transfer of knowledge, the communication of reasoned argument, and persuasion” ((Bemelmans-Videc et al., 1998), p. 33).

There are currently a number of regulative, economic and informative policy instruments relevant for energy-building interactions in Norway (summarized in the table below). This policy framework does not explicitly support solutions for increased interaction, even if there have been recent amendments in the regulation of third-party access and deliveries to district heating. Overall, energy efficiency is not a specifically well-established policy field in Norway (Knudsen and Dalen 2014, Ryghaug and Sørensen 2008). It adds complexity to an "energy efficient transition" that buildings has traditionally not constituted a uniform industrial sector and – within a Norwegian context, at least – has been anchored within and regulated from different policy fields (Rasmussen et al. 2006; Boasson 2009).

At the same time, certainly regulatory changes have been decided during recent years in Norway, pointing towards a clearer political priority of energy efficiency. An important driver behind these changes has been the stricter requirements stemming from EU-based legislation, particularly the Directive on Energy Performance of Buildings (EPBD) which (in particular) implies the compulsory phase-in of 'near-zero energy buildings' by 2020. The EU EPBD requirements are in Norway codified into the Building Code. A number of building companies have started to experiment with the new building energy standards, and several innovative projects – including energy-positive buildings – are now realized in Norway. A number of energy companies, in addition to the ICT sector, are also increasingly interested in this regard.

Table 1 Overview policy instruments for increased energy efficiency and interaction in Norway (Knudsen and Dalen 2014)

<i>Instrument</i>	<i>What</i>	<i>Governance level in Norway (national/regional/local)</i>	<i>Promotes energy efficiency and/or increased interaction</i>
<b>Regulatory</b>	<b>Building regulation TEK 10</b>	National	yes <sup>1</sup> (thermal insulation requirements)
<b>Regulatory</b>	<b>Planning and Building Act</b>	National/local (municipalities set the concrete requirements)	No
<b>Regulatory</b>	<b>Plus customer arrangement</b>	New regulation under development: Owners of residential and non-residential buildings are supposed to achieve the right to exchange up to 100 kW surplus electricity, free of charge (e.g. building- integrated PV to the electricity grid)	Yes
<b>Regulatory</b>	<b>Third-party access/ deliveries to DH infrastructure</b>	National, amendment of the Energy Act (2013): Allowing third parties to access and deliver heat to existing district heating infrastructure, depending on the negotiation with the owner of the infrastructure. (The DH infrastructure owner is not obliged to provide access, if agreement is not reached).	yes
<b>Regulatory</b>	<b>EU Energy labelling Directive</b>	Norwegian Water Resources and Energy Directorate prioritize product groups for closer follow up. National regulations established on a product group base as the EU regulation progress develops into mandatory regulations. Market pull – informing buyers.	yes (market pull)
<b>Regulatory</b>	<b>EU Ecodesign Directive</b>	Same process as for EU Energy labelling Directive. Market push- removing products from market.	yes (market push)
<b>Regulatory</b>	<b>The Energy Act</b>	National. Regulation of income frame for grid operators, tariff regimes for grid operators, producers and end-users of energy, including a regulation of district heating market (mandatory connecting and regulation of pricing).	Yes (energy performance certificates for buildings)
<b>Economic</b>	<b>Enova incentives</b>	National. Supports investments in more energy efficient heating solutions (i.e. hydronic heating, solar water heating, heat demand steering systems, geo-thermal heating), and new technological solutions.	Yes
<b>Economic</b>	<b>Innovation Norway</b>	National. Financial support to energy and environment R&D	Yes
<b>Economic</b>	<b>The Research Council of Norway</b>	Several economic instruments, such as financial support to R&D projects, and tax incentive schemes for companies conducting R&D projects.	Yes
<b>Informative</b>	<b>Energi21</b>	National strategy on energy technology R&D with energy efficiency as one of the prioritized areas. Priorities of the strategy to be taken into account by the RCN in the funding of R&D projects.	Yes
<b>Informative</b>	<b>Bygg21</b>	National strategy on buildings with sustainable, adaptable, functional buildings for the future residential and urban areas.	Yes

<sup>1</sup> [http://www.paroc.no/Knowhow/Building-regulations/Norwegian-Building-regulations?sc\\_lang=en](http://www.paroc.no/Knowhow/Building-regulations/Norwegian-Building-regulations?sc_lang=en)

When discussing possible solutions within a Norwegian context, it is also important to understand the societal and political factors underpinning the current situation – and consider what can be considered as politically feasible. There is a remaining barrier in the way Norwegians consider supply of energy – in the form of electricity, as cheap and abundant. Hence, the overall drivers which are substantially present in other European countries, related to higher energy prices, less security of supply and the need for phasing out fossil fuel-based production of electricity, are not present in Norway. In addition, Norwegian building prices for both residential and non-residential buildings are relatively high. Given the current prospects of increased challenges for the Norwegian economy, such concerns will grow in importance. Hence, additional costs related to energy provision for buildings may not be a very feasible path, and new projects for energy storage and interaction should also focus on and clearly communicate how they can contribute to reduced costs, in order to become more politically robust in a long-term perspective.

With the development of more interactive energy networks which are being introduced with smart grids, we can expect to see more cross-sectoral innovations, combining multiple technologies. Still, with this development comes the growing need for improved energy management systems of e.g. smart thermal grids, and new concepts for energy storage (e.g. geothermal solutions for heat/cool storage). There are challenges emerging related to the management of more integrated systems, and the coordination across traditionally separated technical systems. As mentioned in the previous chapter, these different technical systems (energy/buildings) do also represent different policy sectors with different and fragmented public authorities and different regulatory logics. A major question is how small scale and context sensitive solutions, stemming from a singular or multiple actors within e.g. the building and industrial sectors can represent alternative solutions, and to what extent these approaches can supplement and eventually influence upon the further development of the policy framework.

The following section will explore these questions further by discussing concrete cases from the Norwegian industrial sector.

### **3. Case studies: Implementation of policy instruments and actor induced measures**

The empirical basis of the paper is two cases of building/energy innovation processes; one initiated by private actors and one as a response to governmental incentive schemes. By this the paper raises the questions as to what extent energy-flexible solutions for buildings are promoted by the current policy framework in Norway, and how pilot project actors experience this policy framework.

The case-studies are based on 30 in-depth interviews and a questionnaire. The interviewees represent industry partners, grid owners, municipalities, governmental instruments, building owners, consultants, R&D, and building contractors. We also conducted a document study of all official documents related to the establishment of the specific industry-cluster and regional energy-plans from the municipality and energy-supplier. Finally, a field-visit was done to get an

impression of the cluster and energy-system of case 1. The material was transcribed and analyzed triangulating the different sources of data (Yin 2009). Drawing on the work of Burawoy (1998) and his concept of *extended case-study*, the empirical findings from the case-study is analyzed against a backdrop of Enova and Energy21 quantitative studies of barriers hindering the utilizing of surplus-heat in Norway. By doing so the case-study illuminates the perceived paradox articulated by using a barrier-model to explain the lack of innovation, and a challenging disparity between contextual optimization and regulatory standards and standardization.

### 3.1 Case 1: small-scale energy entrepreneurship

Our case of actor-induced initiatives constitutes heterogeneous solutions for energy efficient systems. Such projects might hold great potential for saving energy, but also for never being realized due to challenges in coordinating these innovative ideas (Johansen & Røyrvik 2014). Multiple buildings, and different kinds of production and consumption making up one system optimized by the differences of energy needs and usage characterize the case we focus on. Given that the object is the optimization of energy consumption and minimalizing impact on the environment, such projects must handle socio-technical heterogeneity – reaching beyond energy-political instruments (ibid).

The notion *collective energy-system* is used because it highlights what we consider to be the greatest innovation in this case; a shared private initiated energy-system with internal rules regarding infrastructure and trading of energy. This can be seen as opposed to a traditional energy system with a grid-owner, producer, distributor and customers. In the collective energy-system at Kviamarka the businesses have multiple roles as they are maintaining their own infrastructure, contribute with energy to the system as well as receiving from the system. The optimalization of the system is defined as a collective responsibility, even though the roles are clearly stated. The *collective energy-system* at Kviamarka involves surplus heat, cooling water and CO<sub>2</sub>.

Kviamarka is an alimentary cluster in a small region in Norway where five different companies have integrated their energy flows into a local sustainable energy-system in order to reduce energy-cost and make the whole region more energy-efficient. The cluster is the only industry-cluster in Norway that utilizes low-temperature heat (35 C<sup>0</sup>) in a *collective energy-system*.

The construction of the collective energy system was initiated by the simultaneous establishment and bridging of two companies: *Tine* were building Norway's largest dairy in Kviamarka which produces a large amount of surplus heat and CO<sub>2</sub>. To utilize this waste-energy *Miljogartneriet* were building their greenhouse next to *Tine* to utilize both the surplus heat and the CO<sub>2</sub> (in the photosynthesis), becoming the first greenhouse in Norway without their own energy-central. Integrating the companies' energy flows was necessary to get political approval for the development plans. When completed, this also led to a more cost-effective production.

At the time *Tine* and *Miljogartneriet* joined, the cluster already consisted of the three companies *Jaerkylling*, *Nortura* and *Prima Jæren* (all chicken producers), which at the time had to use cooling fans to get rid of their low-temperature surplus heat. By connecting to *Tine's* energy

central they could save energy-costs by delivering their surplus-heat, and receive cooling water for a cheap price. By utilizing the low-temperature surplus heat from the cluster in a shared system, *Tine* can also sell this heat to the local energy-supplier which then distributes it to buildings in the nearby town, reducing the need for heating by electricity. Bridging the businesses in the cluster thus made their production more cost-effective along with reducing the whole region's eco-footprint.

In *Kviamarka* this material bridging of companies led to a huge inter-dependence amongst them; *Miljogartneriet* for example cannot maintain its daily production without the energy-input from nearby companies. Another interesting character of the collective energy-system in *Kviamarka* is how some of the agreements are informal and constituted by personal relationships between individuals in the respective companies. Ownership is distributed among the companies, they all own a part of the system and that part is necessary for the whole system to function.

The innovation in *Kviamarka* is not merely the material bridges and energy flows; it is the creation and negotiation of a collective energy-system that binds the companies together and makes them inter-dependent. In the discussion, this will help illuminating some challenges with utilizing cost-effective surplus heat that again explains the limited extent of such solutions today.

### **3.2 Case2: large-scale program**

In the period 2010-2013, a state funding agency aiming at reducing energy consumption in the building sector on a national basis operated a programme to increase the number (proportion) of buildings houses with a *passive house quality*. The program was arranged to provide financial support to consultancy and implementation of solutions that met the criteria of the Norwegian Standard for passive houses (NS 3700 and NS 3701).

During the program period, 751 applications were granted. 182 of these were directed towards consultation within the concept development phase, while 569 were directed towards direct financial support for the implementation of solutions. During the program period several problems occurred. Some of these which may be traced back to the operationalization of the main goal of the agency into a program.

First, the translating of sufficiently low energy consumption into a standard of passive houses, seriously narrowed the scope, from a holistic measure of societal energy consumption into a number of standardized components in individual buildings. The breaking down of a holistic measure into fulfillment at a component/building level excluded solutions where for example clusters of houses in sum fulfilled the goal. As a result, the incentive promoted suboptimal energy solutions where the sum of the individual buildings – in terms of energy saving – actually underperformed clusters of buildings. A case that may serve as an example of this was a project where a series of buildings were originally planned as energy saving townhouses. Paradoxically, when it was decided that they should go for a passive house solution, the townhouse model was rejected in favor of less energy saving detached houses. The reason for this was that the conditions for financial support varied between buildings below and above 200m<sup>2</sup>. To be able to meet the

passive house criteria, and thereby trigger the funding, the developer chose to separate each house by 40m, thus actually receiving support for less energy efficiency than originally planned.

Second, there were serious difficulties related to the measuring of saved kWh of the individual components and buildings. Thus, support was not based on real savings, but on loose estimates of saving. Third, these estimates were made in the planning phase of the projects. The applications were granted in this planning phase, and the only condition to trigger the funding was that the building was reported as completed. There were no standardized processes of control of neither the components nor building energy consumption after completion of the projects. Fourth, the funding agency records of their activities, grants and resulting energy savings were neither well maintained nor easily accessible – neither to themselves or to researchers.

Thus, the operationalization of the main goal raised concerns both regarding goal displacement and measurements. This is a case of a general paradox related to incentives and regulation: Due to decontextualisation of standards, they sometimes produce suboptimal solutions; and due to accountability regimes that permeate the public sector, one tends to produce only that which is measurable. Paradoxically, regulators do not always pay enough attention to the fact that what is measurable is not necessarily aligned with the primary goal, nor are the measurements trustworthy. We find this to be a potential problematic aspect of incentive regulated initiatives.

## 4. Discussion

One of the main findings of case 1 is how the integration of different businesses' energy flows implicates a number of challenges. One is that material 'bridges', that is the physical connection provided by the new infrastructure, between companies implies a need for structural bridge as well. This can be illustrated by comparing a *collective energy-system* with a traditional energy-system. A traditional energy-chain can be illustrated as a number of roles, manifested in companies responsible for performing these roles. *Energy-producers* produce energy for an energy system. Grid owners are responsible for investing in required infrastructure and maintenance. *Distributors* buy energy from the producers on the open market and sell it to *receivers*. The system is institutionalized by laws of the country and energy prices on the open market. The expectations to the system can be characterized as a form of institutional trust (Zucker 1986) and are largely taken for granted.



Fig 1: Traditional energy-system

Fig 2: Collective energy-system

When establishing a collective energy-system these roles must be negotiated. This way of organizing a company's energy-flows is radically different from being connected to a 'traditional' energy-system. In addition to their normal production the businesses must take on new roles as *producers*, *distributors* and *receivers* in the collective energy-system. This involves an inter-dependence where the different actors are dependent on the other businesses' energy-flows for their daily production. The material bridging of the energy flows implies a need for structural bridging by replacing and establish the roles; producer, distributor and receiver. The responsibilities, energy-prices and ownership must be negotiated between the companies instead of being given by institutional structures. Bridging businesses' energy-flows therefore implies several challenges that must be met in order to create a collective energy-system:

- 1) Discover opportunities for bridging and knowledge sharing
- 2) Need for negotiating roles and responsibilities constituting the system
- 3) Emergence of inter-dependence

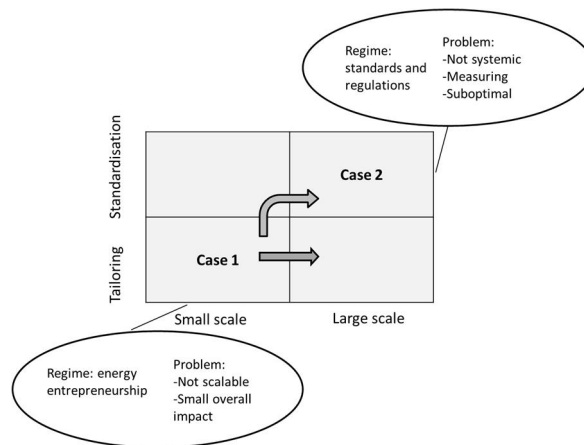
These challenges are all systemic and thus transcend what can be controlled, affected and regulated by instruments that focus on separate and homogenous legal entities. The very way that the industries are organized and how context specific aspects are utilized and made part of the energy system is the innovation that makes the industry cluster energy efficient. Many industry clusters could benefit from such collective energy systems, but this one exact concept would not be optimal for other clusters in different contexts – they would need to adapt to the socio-technical context that constitute their specific situation.

## 4.1 Scale and standardization

The political objective of energy optimization can be pursued through different regimes, with which different strengths and weaknesses are associated. Small-scale solutions can benefit from context-sensitivity and tailor-made solutions to fit local conditions of political, commercial, technological and geographical natures, through the initiatives of what we call energy entrepreneurs. The weakness of such solutions is that they are not scalable, since political, commercial, technological and geographical conditions vary from place to place, and the solutions that work well may therefore vary.



Large-scale solutions benefit from the strength that lies in decontextualized standards, and application of standard based regulatory regimes. By freeing itself from dependence on local conditions, standards work on large scales. The weakness of standardized solutions is that they are often suboptimal. In the passive house program example, the standard that applies is for single buildings (whose reference building does not exist in practice). One weakness of the standard is that it does not allow application on the system level (eg several houses combined) by upscaling. Another weakness is that the parameters used to comply with the passive house program both are difficult to measure and, moreover, not always adequate measures for the overall objective of energy optimization at society level.



*Fig 3: Scale, context and standardisation*

The arrows in figure 3 indicates two possible ways of scaling up the integrated concept presented as case 1. The first solution is to standardize case 1 in terms of components and ways of measuring as it is done in case 2. We would argue that this would involve the same kinds of issues as described in case 2 as the specific solution optimal in the specific case is not similar elsewhere. The second solution is to facilitate arrangements that are both context sensitive and scalable. This is difficult in practice, and one of the central challenges energy efficiency policy is facing.

## **4.2 Organizational framework for smarter and increased interaction between the energy system and buildings**

It is important to assess how changing trends concerning energy consumption in buildings are affected by the existing and upcoming policy framework. It is important to map and assess how certain policy instruments function and how this will impact both the level of energy efficiency in the building stock, as well as future energy consumption. This issue is also closely connected to developing smart grid solutions. Consequently, it is important to pinpoint political and regulatory factors which impact upon the very interface between energy consumption and production related to buildings, and the external energy provision towards the buildings. There are few policy analyses assessing this overall problem within a Norwegian context, implying a need for research on how policies can facilitate for transition towards increased exchange of energy surpluses and energy storage in and between buildings and building complexes.

In the the second case, the program was initiated by the regulators, the target group was conceived/operationalised as a market, and the program was shaped to influence the market – raise the demand – through incentives (subsidies). The belief was that having reached a critical mass of houses categorized as *passive*, the market would see the profitability of “passivehouses” and the incentive would no longer be needed for the market to go for such solutions. At this point, the market would thus be ready for adopting the requirements of “passivehouses ” as a building standard, which could be seen as a final motif.

In the first case, on the other hand, the project was initiated by a group of actors who independent from regulators and regulations agreed to create their own market based on mutual goals and agreements. The regulators involvement in this project was merely as facilitators, without any ambition of creating new standards or of scaling up the project. This project was more actor-oriented, and relating to “market” as a composite, situated entity.

The two projects differ in many respects, not the least in scale; while the second sought to influence the market on a national scale while the second was one single project (but involving several actors). Despite this asymmetry, comparing the cases gives rise to some interesting observations:

1. The weakness of the “market-regulator” approach is that already existing inequalities in the market may be strengthened, and that the movement of the market will not be reversed when incentives are withdrawn rest on assumptions that are yet to be proved. The strength is that one make use of heterogeneous methods for stabilizing the market demand by developing new standards (Tek15) that the market has to follow.
2. The weakness of the actor-oriented approach is that it works on a small scale, and that the projects are highly dependent on mutual trust and stability of the good relations within the projects. The strength is that when the initiative comes from within the projects, the actors are willing to strive hard to realise it. Another strength is that the projects are adapted to the local context, and may thus be more efficient than more standardized projects that are initiated from regulators. In sum, many such actor-initiated projects may add up to a national portfolio that is highly adapted to local conditions, and such approaches may thus be more resilient to changing conditions over time.

## 5. Conclusion

One important finding from our study is that some private initiatives act as driving forces for the emergence of new solutions despite difficult circumstances substantiating regulation; while the majority of building market participants is conservative (Røyrvik et al. 2015) in the way that profitability and predictability are considered the most important thing as long as it is within the rules and regulations. This actualizes a duality, as rules and regulations both need to allow and promote private heterogeneous initiatives while also providing a clear direction for the development of the building and energy market as a whole.

Although there is an increased focus on energy efficiency in buildings, there are no explicit policy measures in place in today which directly aim at stimulating more energy storage (i.e. thermal storage in this report) and exchange between buildings. Still we have to be aware of what is politically feasible. Given the Norwegian situation with little focus on security of supply, low electricity prices – but high costs related to the building sector; there are few political incentives for 'extra-charging' Norwegian energy consumers for building owners' innovative energy measures.

We find that the policy instruments are faced with an inherent dilemma in the regulation of higher energy-efficiency: On one hand, context-sensitive regulation is necessary for energy entrepreneurs to realise creative solutions under local political, commercial, technological and geographical conditions. At the same time, context-sensitivity and energy flexibility may often be at odds with regulation based on standards, which we see as the prevailing measure for large-scale impact. We advise more research on how regulation may enable large-scale strategies to incorporate small-scale initiatives that take stock of the local context. This is challenging, since context-sensitivity and standardization tend not to always go well together. However, we believe this is not a question of standardization or not. Rather, we believe that research aimed at addressing potential better objects of standardization than those dominating today – components, systems and buildings – may be fruitful.

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# Negotiating water governance: towards cooperation in contentious groundwater recharge projects

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## Abstract

Water services are an essential part of urban planning and strongly connected to the field of natural resources management (NRM). During the last few decades, Finnish community water supply has increasingly relied on groundwater as raw water source. However, inter-municipal groundwater projects have become contentious issues in Finland and several examples of prolonged projects with years of litigation can be found. A contentious groundwater project can be classified as wicked problem employing features of complexity: it is unpredictable, uncontrollable, and has several, often contradictory interpretations. In addition, several domains are intertwined in the natural, built, and socio-economic environments of the water sector. The complex nature of groundwater management was examined in two cases of prolonged *managed aquifer recharge (MAR)* conflicts in Finland by applying discourse analysis and negotiation theory. The main objective was to find new perspectives for groundwater governance by analysing the major constraints of those projects by drawing from collaborative approaches, which are widely acknowledged in the fields of urban planning and NRM. Results indicate that instrumental rationality with rationalistic planning approaches still prevails in Finnish groundwater management sector. Interaction and knowledge production based on those approaches are insufficient in responding to complex management problems, especially those with contentious features. Thus, this study suggests that the core of groundwater governance should be in collaborative rationality, while the tools can be obtained from rationalistic expert-based planning. The legitimacy for a complex groundwater project should be gained through joint knowledge production as well as mutual interaction, acknowledging stakeholders as partners who are an invaluable asset for dealing with current groundwater management problem.

**Keywords:** discourse analysis, groundwater governance, natural resources management, negotiation theory, urban planning

# 1. Introduction

Groundwater is an invaluable part of our natural, built, and socio-economic environments. However, since it is out of sight, we often forget its value and its quantity: approximately 95% of available freshwater sources, excluding those locked in polar ice caps, are underground (UNEP, 2003). During the last few decades, Finnish community water supply has increasingly relied on natural and artificially recharged groundwater as raw water source. In 2011, their combined share of the water supplied reached 66%, out of which 16% is artificially recharged<sup>1</sup> (Katko, 2013). However, due to geological reasons, potential groundwater areas and places for groundwater recharge are sparse. Thus, large city centers, with their increasing need for fresh water supply, are obliged to withdraw groundwater from afar, often crossing municipal borders. This may cause tensions between different jurisdictional units, generally between rural and urban areas. Indeed, there are several examples of local conflicts around the inter-municipal groundwater projects in Finland (Junes, 2013; Lyytimäki and Assmuth, 2015; Myyrä, 2007; Rossi, 2014). Projects which are justified on both technical and economic grounds have problems in gaining legitimacy among local inhabitants. Oppositions emerge and projects may go through long litigation processes.

Large-scale groundwater projects can be classified as wicked problems employing features of complexity: they are unpredictable, uncontrollable, and have several, often contradictory interpretations (Rittel and Webber, 1973; Islam and Susskind, 2013). Therefore, they pose several challenges to water managers and planners in the context of conventional groundwater management approaches. Conventional rationalistic planning cannot respond to a situation where contradictions among stakeholders and political debates may overshadow rational analysis (Sotarauta, 1996; Nolon et al., 2013). Indeed, the emerging paradigm emphasizes collaborative approaches to complex management problems in the fields of urban planning (e.g., Healey 1998, Fainstein 2000, Edelman 2007, Martinez and Olander 2015) as well as natural resources management (e.g., Singleton 2002, Conley and Moote 2003, Margerum 2011, Ostrom 1990).

This paper is based on a doctoral thesis, expected to be published in June 2016. The study aims at finding new perspectives for groundwater governance by analysing contentious cases that operate in the context of water services, thus connecting the fields of urban planning and natural resources management (NRM). Water services, which include water supply, wastewater treatment, and storm water management, are inherently bound to these fields through the multiple connections with aquatic environment, required technical infrastructures, and influence on socio-economic development. Accordingly, this research analyses the major constraints in two large scale managed aquifer recharge (MAR) projects from the perspective of collaborative governance and outlines lessons for future collaboration.

First case is situated in southwestern coastal area of Turku Region, and it started already in the 1970s as a long-distance water transfer project and was finalized in 2010. The other MAR project, situated in Tampere Region, started in 1993; the result is still open (Figure 1). More particularly, in the analysis of

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<sup>1</sup> Later in this paper the term *managed aquifer recharge* (MAR) will be used in order to refer artificial groundwater recharge.

the two case studies, this study applies discourse analysis (Hajer, 1995) and negotiation theory (Walton and McKersie, 1965; Fisher et al. 1991; Bartos, 1995), which is the base for several consensus-oriented practices, including alternative dispute resolution (ADR) (McDonnel 1988, O'Leary and Raines 2001), consensus building (Susskind et al. 1999) and mutual gains approach (MGA) (Susskind and Field 1996, Nolon et al. 2013).



*Figure 1: Geographical locations of the two case studies*

In both case studies multiple materials were available. However, the primary material for the first case study was newspaper articles (approx. 400 pcs, 1999–2010), from which a discourse analysis was conducted. A discourse analysis explores the ways reality is constructed through discursive practices in texts and talk (Nikander, 2008). In this case, the study analyses the argumentation used in newspaper articles and recognizes the ways these texts constructed and maintained discourses around the MAR project. Second case included 28 semi-structured interviews and a conflict assessment process with a workshop which convened representatives of almost every stakeholder group. The results of conflict assessment were viewed through negotiation theory (see Kurki and others, 2015 as well as Kurki and Katko, 2015 for more details about the case studies and the analysing processes). Overall, the analyses of these two case studies clarified the visible tip of the iceberg of conflicts as well as the large invisible entity, which is often forgotten beneath the surface.

## 2. Results

In Finland, municipalities have a responsibility to organize water services. Increasing challenges of water quality requirements, aging infrastructure, and decreasing fiscal resources have furthered collaboration between municipalities. In both case studies, municipalities joined forces in order to produce enough good quality fresh water for domestic and industrial use in an efficient, economic, and ecologically sustainable manner. Accordingly, in both regions, a municipally owned water company was established with its main task to plan and implement an MAR project in order to achieve this goal.

Managed aquifer recharge (MAR), also known as artificial groundwater recharge, is a technological innovation where natural system of water purification is exploited as part of water supply system. It has been used for decades, mainly as a water treatment method in boreal areas (Kolehmainen, 2008), whereas in arid and semi-arid regions for freshwater storage (National Research Council, 2008; Shahbaz et al., 2008) and in reuse of storm- or wastewater (Barnett et al., 2000). This method is widely used and gains continuously increasing attention inside groundwater management discussions and practices, especially in terms of technical, economic and legislative considerations (Bloetscher, 2014; Dillon et al., 2010). However, a comprehensive framework for MAR is lacking. This study presents such a framework, which acknowledges the complexity of water systems as well as perspectives of collaborative governance.

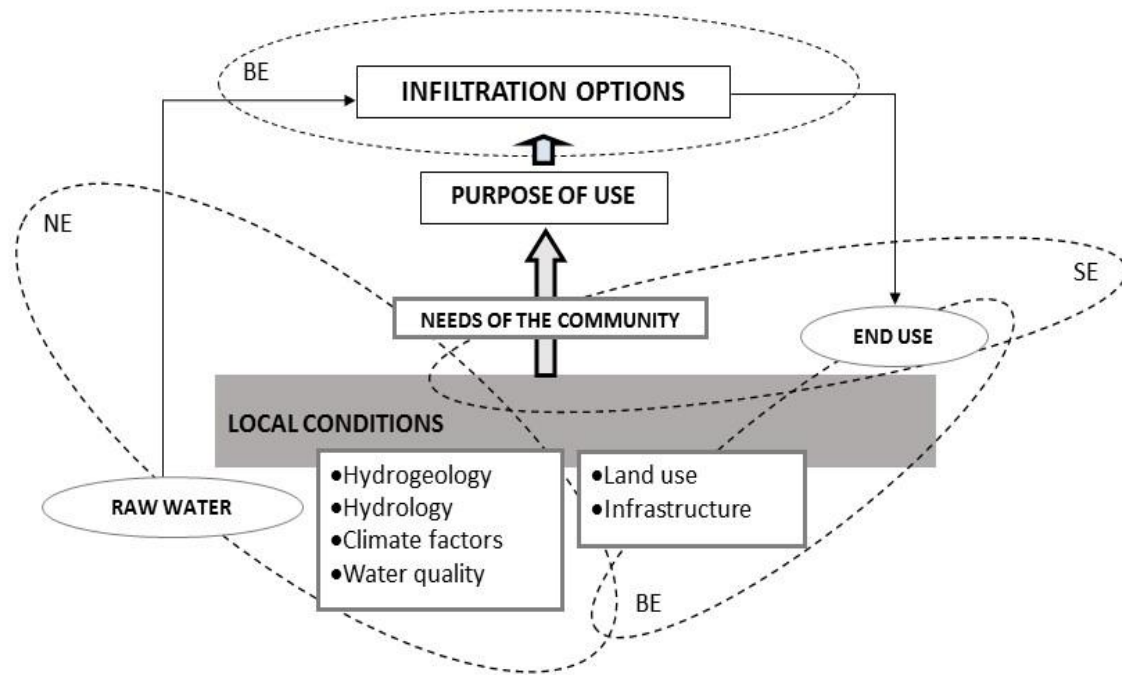
### 2.1 A comprehensive framework for MAR

Water is inherently bound to our natural, built, and socio-economic environments. Conventional water management approaches often underestimate the first or third domain, or address all three of them but as separate entities. However, for example, Swyngedouw (2004) describes their interconnected relationship where social practices are predicated upon and conditioned by the circulation of water into, through, and out of the city. According to Linton and Budds (2014), the hybrid nature of water means that it is simultaneously both a natural and a physical element, as well as a social one.

Accordingly, Figure 2 presents a comprehensive framework for MAR where all three environments are acknowledged. From a technological point of view, the framework of an MAR project consists of three main components. First, the base of an MAR project is in its *local conditions*, which are characterized by the natural as well as physical environments. Second, the needs of the community arise from the local conditions and together they define the *purpose of MAR*, which in Finland is generally water treatment. The communal needs are clearly part of socio-economic environment, and interconnected with economics and legislation, which all affect the implementation of an MAR system. Third, the local conditions and purpose of MAR together influence the selection of *infiltration options* which consist of technical design parameters needed for an MAR system, thus being strongly connected to the built environment.

Finally, the outcome of an MAR project is the chain from water intake to infiltration and end use. In this chain, all three environments are present. Raw water is taken from its natural environment; infiltration options represent the physical, built environment with water transfer pipes, excavated basins, and constructed recharge wells; and finally, the processed water is delivered to the community, to the

socio-economic environment. Through this process, the material form of water is modified, but also local conditions and social structures change along the way. Thus, once an MAR system is established, it does not remain stable. Instead, the system is dynamic in its spatial and temporal dimensions, and new socio-natural configurations emerge (Linton and Budds 2014). Consequently, the system involves several characteristics of complexity: nonlinearity, unpredictability, and uncontrollability.



*Figure 2: A comprehensive framework for MAR and interrelations between natural environment (NE), built environment (BE), and socio-economic environment (SE) (modified from Kurki et al. 2013)*

In groundwater governance and especially in MAR cases, a strong connection to land use and spatial planning should be acknowledged (see Hartman and Spit, 2014). An MAR project has indirect impacts on land use through it potentially causing restrictions for other land use activities as well as direct impacts through constructed pipeline network and infiltration areas. However, groundwater issues also involve a mental feature in connection to land use: an underground resource is often regarded as a property of the landowner, even though according to Finnish legislation groundwater cannot be owned by anyone. Accordingly, MAR conflicts can be also regarded as land use conflicts, thus intertwining the features of common-pool and non-common-pool resources. This may cause mental confusion, which forwards the contradictions related to groundwater projects.

## 2.2 Major constraints in groundwater governance



The complex nature of an MAR system was not recognized in the two cases. Instead, they were managed as merely technical problems, to be solved by using a sufficient amount of expert knowledge. The definition of a problem derived from a mechanistic worldview where a system can be taken apart, the details of those parts analysed, and feasible partial solutions being thereby found (see Islam and Susskind, 2013). Especially the social dimension of the system was not adequately acknowledged. Therefore, interaction between various parties failed and a conflict emerged. Drawing from negotiation theory and discursive framework, the paper presents the discursive order and the major constraints observed within the two contentious MAR projects.

In both cases, strong positioning of various parties was formed during the decades of dispute, leading finally into a deadlock where the only aim of the opponents (composed mainly of local residents) was to turn down the project, and the only aim of the proponents (the water company owned by the municipalities) was to implement it. Discourse analysis, clarified how a strong environmental discourse was formed around the MAR projects. It was constructed and maintained by several parties: while the opponents addressed the possible environmental threat that an MAR plant would bring to the area, the proponents claimed that MAR technology is an environmentally friendly way to produce drinking water. In fact, environmental discourse dominated the visible structures of social orders and overshadowed a latent but important regional policy discourse.

The regional policy discourse was formed around a concern for local economy, that it would be threatened by the MAR projects since they would cause tightening land-use requirements and environmental restrictions for local economic activities. This does not mean that the environmental arguments of local inhabitants were false, but it does indicate that the real interests and values are hidden under strong positions that actors take (Susskind, 1999). Accordingly, one major constraint of the two projects was that the actors concentrated on their predefined goals through their fixed positions and did not acknowledge the underlying interests of the other side. This kind of competitive mindset was accompanied by interaction based on zero-sum game and hard bargaining where the main purpose is to defend one's own goals with as minor concessions as possible and to maximize the share of the fixed amount of benefit (Bartos, 1995; Fisher et al., 1991).

Another constraint is related to the knowledge production process. Knowledge is one of the fundamental elements for building legitimacy in complex processes. It is, however, also a medium for clashing claims. Expert knowledge was acknowledged as a sole legitimate source of information, but expert-based arguments from the water managers and planners did not calm down the opposition; instead, they worked as a fuel for even stronger counter-argumentation. This indicates the presence of instrumental rationality, which is in line with the idea that contradictions can be solved by increasing the amount of expert knowledge. Yet, this assumption is questioned by several scholars (Nelkin, 1979; Pellizzoni, 2003; van Buuren, 2009) and also by this research.

Finally, the results indicate that conventional groundwater management approaches, which derive from instrumental rationality, could not respond to the problems that operate in a complex environment. Although collaborative efforts were implemented, they were used only as casual tools without really relying on collaborative rationality.

## 2.3 Collaborative groundwater governance

The analysis of two MAR projects brought up several challenges in planning and implementing complex groundwater projects. In order to answer those challenges, this section presents some comparisons between conventional groundwater management and collaborative groundwater governance. These frameworks are drawn from two sources: on one hand, from literature on collaborative governance, including multiple case studies, theoretical considerations, and pragmatic guidebooks; and on the other hand, from those lessons that we can draw from the pitfalls of the two case studies. However, complex problems do not fit into any single governance model, which often offer too simplified a picture of the world (Ostrom 1990). Every situation is different; thus, practitioners need to translate solutions derived from scientific findings into the confused context of the policy world, where natural, built, and socio-economic environments need to be considered. While no universally correct answers are available, this study indicates some directions towards collaborative groundwater governance.

Whereas the goal of conventional groundwater management is to achieve outcomes that fulfill technical, legislative, and environmental requirements, in collaborative groundwater governance the whole process is defined by legitimation. Legitimacy here is understood as tacit approval (Häikiö 2007) where actors recognize, approve, and support the process, practices, and outcomes. It needs to be gained from the perspective of all three domains that are ultimately present in groundwater processes: natural, built, and socio-economic environments.

While analysing the major constraints faced by the MAR projects, two significant aspects arose above others in the process of legitimation: interaction and knowledge production. Failed interaction can form an insurmountable barrier between parties, whereas successful interaction can construct a bridge even between contentious interests of various parties. Accordingly, interaction based on zero-sum game involves an idea of fixed amount of benefit that needs to be allocated among the stakeholders (Islam and Susskind, 2013). Parties negotiate from the perspective of their positions rather than of their interests; thus, this creates only winners and losers, and fosters mistrust and hostility. However, in collaborative groundwater governance, interests of every party should be acknowledged and brought to the negotiation table. That way, parties can come out from behind their positions and are able to search for creative solutions and new potential options for reaching mutual gains.

Knowledge production, which is inherently bound to the interaction between parties, is in conventional groundwater management driven by an assumption of perfect and objective information that can be obtained by expert analysis. However, in complex cases this assumption leads to a deadlock. Disagreement about the facts also prevails among the experts themselves (Jarvis, 2014). Indeed, MAR projects form fruitful ground for a kind of duelling expert syndrome. Therefore, it is vital to find legitimate ways to gather the knowledge base, which then forms a cornerstone for the collectively produced truth about the problem. A legitimate knowledge base is created together with experts and stakeholders in a joint knowledge production process, where expertise is exploited as a fundamental source of knowledge but it is complemented with local, experiential, and other forms of non-scientific knowledge (see Ehrmann and Stinson, 1999; Jasanoff and Martello, 2004; van Buuren, 2009).

In these settings, the role of water manager changes from the holder of the only legitimate source of knowledge to a facilitator or even a mediator who has the key to expert-based knowledge as well as to the sources of collective knowledge production. Water manager could also be a conveyor whose main task is to construct and maintain collaborative process and to ensure that every relevant stakeholder is gathered around the negotiation table.

### **3. Conclusions**

Water services are strongly bound to the fields of urban planning as well as natural resources management (NRM). They are often considered as separate fields of inquiry, but they both are an intrinsic part of societal development and thus inherently bound to each other. In addition, urban planning and NRM both involve planning with complexity as well as interactions inside natural, built, and socio-economic environments. From the perspective of governance, both fields widely acknowledge the contribution of collaborative approaches in planning practices.

The objective of this study was to find new perspectives for groundwater governance by analysing two contentious MAR projects and the major constraints from the perspective of collaborative governance. Groundwater conflicts are less frequently analysed than those around surface water projects (Jarvis, 2014). Furthermore, the rather abundant water resources of Finland constitute a very interesting context for studying water conflicts. Although the southwestern coastal area lack adequate water resources in terms of water quality and quantity, from global perspective the rhetoric of water scarcity loses its argumentative power. Indeed, the two case studies support the argument presented in a report published by OECD (2011): water issues are not primarily a result of water scarcity, but rather they indicate significant challenges in the field of water governance.

The two case studies showed how conflicts were formed around two elements: interaction and knowledge production. Having competitive mindsets, the parties' interaction was based on zero-sum game and the discussion was dominated by arguing about facts instead of acknowledging various interests and the complexity of the problem. In addition, the knowledge production process relied on instrumental rationality where the only legitimate source of knowledge is expert knowledge and the causal effects form the basis of the analysis. Complex problems do not, however, follow the logic of a machine: a machine can be classified as a complicated problem with its multiple interactions, but it does not involve unpredictable and uncontrollable elements as societal issues do in their complex appearance.

A complex system should be considered as a whole rather than as a sum of its parts. To complexity we need to answer with complexity: instead of trying to resist and control the system, we can adopt to complexity through collaborative approaches, which can be seen as complex adaptive systems themselves (Innes and Booher, 2010). Collaborative governance framework acknowledges the uncontrollable and unpredictable nature of groundwater management problems and tries to find mutual gains and win-win options for cooperation by stepping away from strong positions and addressing stakeholders' interests instead of predefined goals. Here, the complex nature of the system is seen as source of adaptation rather than control.

Yet, if we use new tools in an old manner, the result will probably remain the same. Thus, the *core* of groundwater governance should be in collaborative rationality, while the tools can be obtained from rationalistic expert-based planning; not vice versa, as the examples derived from the two case studies show. The legitimacy for the project should be gained through joint knowledge production as well as interaction, where stakeholders are viewed as partners who are an invaluable asset for dealing with current groundwater management problems.

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# **Innovation towards low energy buildings and the role of intermediaries in the transition - Review of Scholarly Case Studies in Europe**

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## **Abstract**

As buildings throughout their lifecycle account for circa 40% of total energy use in Europe, reducing energy use of the building stock is a key task. This task is, however, complicated by a range of factors, including slow renewal and renovation rates of buildings, multiple non-coordinated actors, conservative building practices, and limited competence to innovate. Drawing from academic literature published during 2005-2015, this paper carries out a case study review of low energy innovations in the European residential building sector, analysing their focus and drivers. Specific attention is paid to the roles that intermediary actors have in facilitating innovation processes and in creating new opportunities. The article addresses the following research questions: What is the current status and range of innovation and diffusion in the field described in zero carbon and/or low energy innovation scholarly case studies in Europe? What have been identified as the key factors influencing the development and diffusion of innovations in these case studies? And, what are the nature, type and influence of intermediaries contributing to the low energy building transition? The analysis of the case studies is informed by innovation studies, and specifically by the concepts of the multi-level perspective on socio-technical change and strategic niche management. We find that the qualitative case study literature on low energy building innovation is limited, particularly in the context of existing building stock. Environmental concerns, eco-social values, EU and national policies, and increasing energy prices have been the key drivers, while local authority agents as intermediaries have been important in several innovation processes. On the other hand, market, health and design related drivers were surprisingly rare.

**Keywords:** low energy building, building energy efficiency, built environment, innovation intermediary, innovation



# 1. Introduction

System level innovation has been called for to achieve reduction in the energy use of buildings (e.g. Mlecnik, 2013) that at present amounts to circa 40% of the total energy use and over 30% of greenhouse gas emissions in Europe (Meeus et al., 2012). In the context of achieving significant low energy transition in the building and housing sector, both diffusion of existing technologies as well as the emergence and diffusion of novel system and architectural innovations for residential buildings (e.g. Mlecnik, 2013) are needed. System innovation refers to the integration of *several independent innovations* (e.g. technical products, applications, services) to work together to perform new functions or to improve performance as a whole (Cainarca et al., 1989), while architectural innovation is defined as novel *combinations of existing technologies* and components in a novel way (Henderson and Clark, 2004). These differ from modular innovation that is typically one specific technology (Henderson and Clark, 2004), such as better windows or building-integrated solar panels.

The renewal rate of buildings is extremely slow (e.g. Meeus et al., 2012). Changes to the building stock are relatively rare, and thus at those times when buildings are addressed via renovation or new build, system innovation is important to generate maximum improvement. Innovation and diffusion in the sector are, however, difficult due to a variety of factors making the current regime very stable. Despite country specific variation in the nature of the building stock, building related practices, cultural preferences, regulatory context, building industries and climatic conditions, many commonalities have also been found. The building sector often consists of a multitude of actors who have not structurally coordinated their activities (e.g. Tambach et al., 2010; Killip, 2013) and who do not have competence or resources to innovate independently (Mlecnik, 2013). The building sector is often conservative, especially regarding renovation processes, building materials and work habits (e.g. Davies and Osmani, 2011; Killip, 2013). Also, devising solutions to the high energy problem is difficult due to heterogeneous building ownership and housing arrangements (e.g. Meeus et al., 2012). Additionally, some countries, such as the UK, face tendencies towards mere incremental innovation (Lees and Sexton, 2014) with a building industry that is unwilling to deviate from traditional masonry methods and work habits (Tambach et al., 2010; Davies and Osmani, 2011; Killip, 2013) and often lacks specialist skills (Killip, 2013). “Contrary to this situation, sustainable buildings require (to a varying extent) high-tech components, which are supplied by specialized companies (building control technologies, windows, heating systems, use of solar energy, transparent insulation materials, heat recovery systems, etc.)” (Rohracher, 2001, p. 138).

Drawing from the above it is clear that achieving systemic – or even architectural – innovation in the building sector is challenging both in terms of (1) creating networks and gaining support for the emergence of niche innovations as well as (2) disrupting the high energy institutions and practices of the existing socio-technical regime. Many scholars have explored the topic in different local and national contexts in Denmark (Holm et al., 2011), Belgium (Mlecnik, 2010, 2013), Finland (Heiskanen and Lovio, 2010; Pässilä et al., 2015), Slovenia (Broto, 2012) and the UK (Lovell, 2007; Fawcett, 2014), while overarching analyses are rare (with the exception of Meeus et al., 2012). Therefore, we undertake a systematic review of the literature, focusing on

case studies, to explore the status, drivers and barriers for low energy building innovation in Europe.

Taking a long-term transitions perspective, we connect to two core theories in the field of sustainability transitions (cf. Markard et al., 2012): the multilevel perspective (e.g. Geels, 2002) and strategic niche management (e.g. Smith and Raven, 2012). These theories are used for building an analytical framework for the systematic review (cf. Petticrew and Roberts, 2006) of case studies to draw broader lessons on the role of niche, regime and landscape factors in these processes. In addition, we pay particular attention to whether specific intermediary actors (cf. Hargreaves et al., 2013; Kivimaa, 2014) have been present in facilitating the innovation processes and in what ways. Innovation intermediaries, i.e. "actors who create spaces and opportunities for appropriation and generation of emerging technical or cultural products by others who might be described as developers and users" (Stewart and Hyysalo, 2008: 296), have been envisaged as keystone players in the ecosystems where innovations develop (Clarysse et al., 2014), and they could be crucial also in building sector innovation.

The article addresses the following research questions:

1. What is the current status and range of innovation and diffusion in the field described in zero carbon and/or low energy innovation scholarly case studies in Europe?
2. What have been identified as the key factors influencing the development and diffusion of innovations in these case studies?
3. And, what are the nature, type and influence of intermediaries contributing to the low energy building transition?

Section 2 presents the theory informing our analyses, followed by a description of the research approach and method in Section 3. Section 4 presents the findings of the case study review. Section 5 discusses and concludes the paper.

## **2. Sustainability transitions and intermediaries**

### **2.1 Multilevel perspective and strategic niche management**

The literature on sustainability transitions addresses the problem and dynamics of how to transform existing socio-technical systems to more sustainable configurations. The socio-technical approach implies radical changes not only in technology but also in the surrounding actor-networks, policies and institutions, and people's habits, practices and culture (e.g. Markard et al., 2012). While the sustainability transitions approach entails a range of theories, the multilevel perspective (MLP) and strategic niche management (SNM) have been some of the most frequently applied. In the MLP, transition is depicted through interaction between changes in three levels: the landscape, socio-technical regime, and niche (e.g. Geels, 2002, 2011; Smith et al., 2010). The socio-technical regime refers to the fairly persistent deep structure formed of dominant technologies, infrastructures, formal and cognitive rules including public institutions and policies, and the prevailing networks of actors with their practices, beliefs and habits. As

opposed to, for example, car-based mobility regimes, Rohrer (2001, p.143) has described building regimes as “rather loosely coupled systems depending on the interaction of various professions (architects, planners, building services, etc.)”, building codes, that regulate the technical standards of buildings, providing “a rather wide framework defining minimum standards—especially with respect to criteria of sustainability (energy use, waste, durability, materials used, etc.)”. The building regime is composed of the dominant construction industry as well as maintenance and repair practices, markets and business models in both new build and renovation, regulation and policies influencing the building infrastructure, planning and building control practices, as well as how people perceive buildings and live in them (Figure 1).

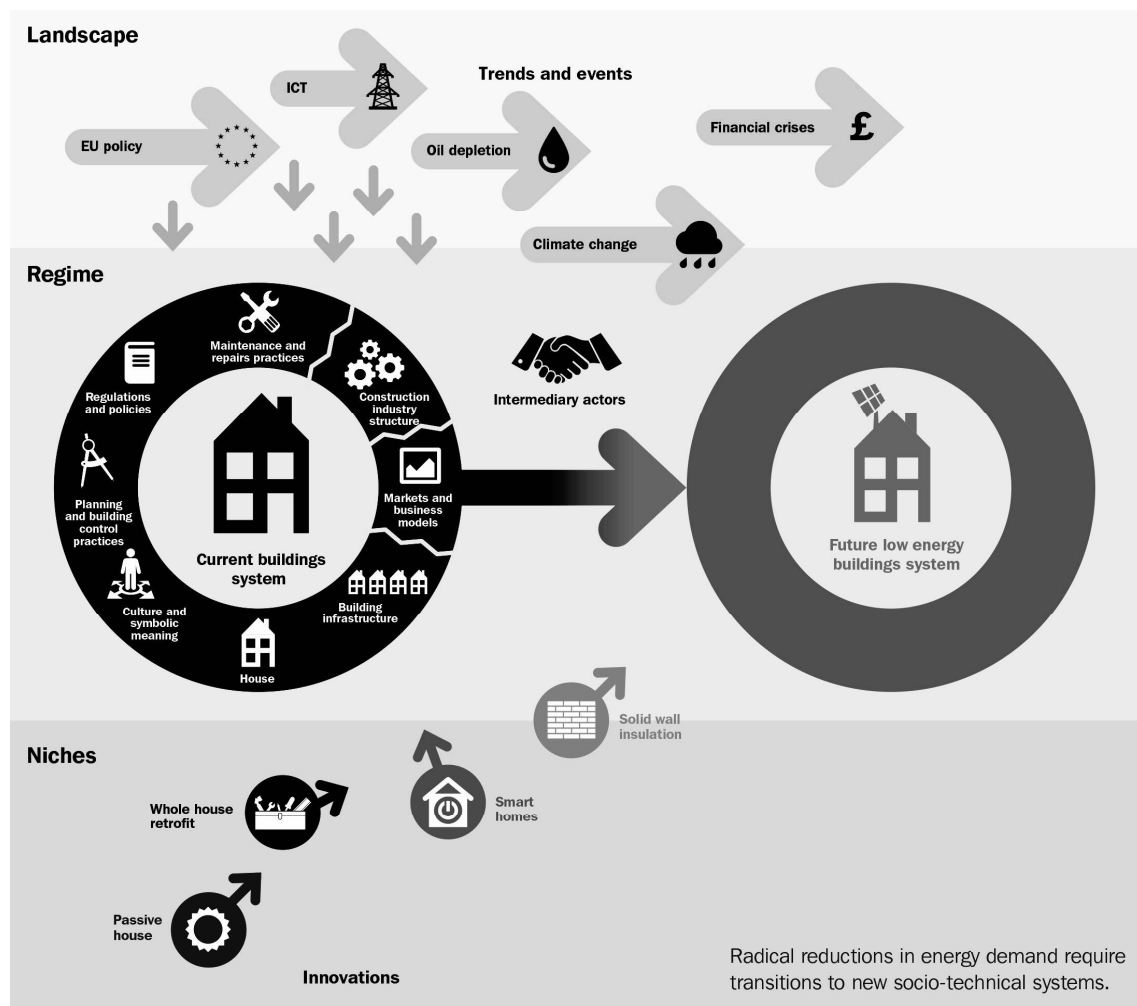


Figure 1: Niches, regimes and landscape in building low energy transition (CIED, 2015))

While incremental innovation is regarded to occur within the context of the existing socio-technical regime, radical innovation activities occur in niches that are associated with initially unstable socio-technical configurations (Kemp et al., 2001; Hoogma et al., 2002). According to SNM, niches provide spaces of protection for radical innovations (Smith and Raven, 2012). In the building sector, concepts such as passive houses and smart homes (Figure 1) can be regarded as radical innovations that develop in niches and have not diffused yet to mainstream building regimes. Processes of articulating expectations, creation of new networks and sharing learning

have been identified as key for successful niche development (Hoogma et al., 2002; Schot and Geels, 2008). These processes facilitate the emergence and diffusion of innovations, making them more likely to embed into and gradually change the dominating regime (Smith and Raven, 2012).

The landscape level is the hardest to influence, existing largely beyond regime and niche influence (e.g. Geels and Schot, 2007) and includes the broader context in which a socio-technical system, such as the building sector, is situated in. It is formed of macro-economic, macro-political and cultural forces, patterns and development trends, such as climate change and the financial crisis (Figure 1) creating pressure for changing socio-technical regimes and opening for new innovation niches. The concepts in Figure 1 were used to guide the systematic case review.

## 2.2 Innovation intermediaries in transitions

In innovation studies, intermediaries are perceived as crucial actors facilitating innovation processes (Howells, 2006; Boon et al., 2011). An innovation intermediary has been defined as “[a]n organization or body that acts as an agent or broker in any aspect of the innovation process between two or more parties” (Howells, 2006). The transitions literature recognises that actors and agency are important (e.g. Meadowcroft, 2011). Yet intermediary actors have received little attention, although van Lente et al. (2003) argued over a decade ago that ‘systemic intermediaries’ are important for long-term and complex changes, including transitions to sustainability. A few previous studies have shown that intermediary actors can facilitate the SNM processes in a variety of ways (Hargreaves et al., 2013; Kivimaa, 2014).

Much of the previous literature on innovation intermediaries focuses on arbitration between the developers of innovations and their users (e.g. Howells, 2006; Stewart and Hyysalo, 2008). Individual studies of a range of actors that could be considered as intermediaries have been published, including consultants (Bessant and Rush, 1995) and university technology transfer agencies (Macho-Stadler et al., 2007). In addition, innovation centres, science parks and innovation financing agencies have been listed as potential intermediaries in innovation processes (e.g. Howells, 2006; Polzin et al., 2015). The previous literature on innovation intermediaries focuses also on intermediation in the emergence and first adoption – rather than diffusion – of innovations. Often the range of intermediaries addressed have narrowly focused on direct innovation oriented actors and not all actors with potential effects on innovation. Alternative types of innovation intermediaries, such as internet market places or energy service companies have been less explored.

A variety of actors operate in the building sector that could act as potential “low energy” innovation intermediaries. In previous literature, for example, architects (Fischer and Guy, 2009; Davies and Osmani, 2011), building managers (Grandclement et al., 2015) and regulators (Holm et al., 2011) have been identified to play potential intermediary roles, while their influence in low energy transition is by no means certain. For example, Davies and Osmani (2011, p. 1692) have found that there are no legislative drivers to motivate architects to “*positively engage in low carbon housing refurbishment design*” and at present architecture companies do not generally take this on as a dominant activity. In other countries, organisations such as foundations (Kivimaa, 2014) and innovation platforms (Mlecnik, 2013) have been identified to intermediate successfully

in advancing low energy housing innovation. In addition, Parag and Janda (2014) have examined religious congregations, building professionals, and commercial building communities from the perspective of intermediation in low energy innovation.

### **3. Research approach and method**

The research approach taken in the paper was a systematic review (Petticrew and Roberts, 2006) of case studies using Scopus, in a qualitative manner. Following Gerring (2004), we understood a case to mean an empirical study describing a process of low energy building innovation, involving measures such as residential housing refurbishments and zero carbon new build homes.

We first limited the year of publication search to 2007-2015, a year after the introduction of Directive 2006/32/EC on energy end-use efficiency and energy services (later repealed by the Directive 2012/27/EU on energy efficiency). The search was limited to peer-reviewed journal articles for ease of access and replicability. The contents of the abstracts of 93 hits were analysed using the following inclusion and exclusion criteria: (1) articles outside the discipline of social sciences and humanities were excluded; (2) to have a connection to innovation studies, the article had to contain the word ‘innovation’ somewhere in the article title, abstract or keywords; (3) to have a common geographical (and political) frame of reference articles outside the EU were excluded from the analysis; (4) to be included in the review, the article had to contain an empirical case study describing a process of low energy building innovation. The case study review, thus, only included so-called ‘uncontrolled’ real life case studies. A caveat of such case study review is that “[u]ncontrolled studies are more susceptible to bias than studies with control groups, so their results should be treated with caution” (Petticrew and Roberts, 2006: 65-66).

“Innovation” was used as a search word in all the 40 search term combinations due to our explicit focus on innovation case studies, and innovation being a very widely diffused word. Each abstract appearing in the Scopus searches was read through to see whether the content really related to what we were searching for. As the initial review only resulted in 18 peer-reviewed journal articles, we extended the review to hand searching the bibliographies of the initially identified 18 sources (cf. Petticrew and Roberts, 2006). In addition, we extended the review of journal articles to a ten year range from 2005 – 2015. Due to our focus on ‘current status’, we viewed a review of the past 10 years more than sufficient. The purpose of the systematic case study review was to examine events anticipating and subsequent to the EU policy on energy end-use efficiency and energy services. Hand searching the bibliographies of the 18 articles and analysing the contents of those articles that had the theme ‘buildings’ or ‘homes’ in the title and matching the above inclusion/exclusion criteria resulted in 2 further relevant articles and 2 cases for the review. Despite extending our search, we, thus, ended up only with 20 peer reviewed journal articles that we subjected to systematic content analysis. Seven articles were subsequently excluded as the more detailed analysis revealed the non-existence of case studies. The 13 articles included in the review contained a total of 25 case studies; five cases described in more than one source article.

Two researchers coded each article first separately following a joint excel categorisation building generic innovation study categorisations of innovation, literature on intermediation and the MLP.

## 4. Findings

### 4.1 Overview of the innovation cases

Although in practice multiple demonstration projects and pilots around low energy new builds and retrofits have been carried out all over Europe, our review finds that very few have been subjected to academic scrutiny and in-depth qualitative analysis from an innovation studies angle. This is besides the wealth of research on the technical qualities, economics, architectural design, domestication, and the policy and politics of low energy buildings. What is also surprising is that what can be classified as qualitative case studies of low energy building innovations or projects promoting them, were found to concentrate only in five EU member states (Belgium, Denmark, Finland, Slovenia, UK). Our attempts to identify scholarly papers addressing these innovations in what can be regarded as front runner countries, such as Austria or Sweden, were unsuccessful.

The cases were predominantly focused on new build, as only three of the 25 cases related to the existing building stock. The nature of innovation in the cases was varied, including piloting sites for ecological living (n=4), architectural innovation resulting in new buildings combining a range of energy efficiency and renewable energy measures (n=7), large scale energy efficient housing development or refurbishment involving systemic and architectural innovation (n=4), innovative processes showcasing and promoting the commercial application of new low energy housing concepts (n=6), creating a new low energy house business model (n=2), adopting modular innovation by mainstream building companies (n=1), and conducting a renovation project towards a passive house standard (n=1).

In all but one case, a variety of different motivations and drivers were evident, and several cases had more than one key driver. The key drivers can be broadly divided to the following eight categories (in the order of importance):

- *Environmental drivers* (e.g. green values, environmental concerns, climate change)
- *Eco-social drivers* (e.g. eco-social movements, communal living, alternative lifestyles)
- *Policy drivers* (e.g. local, government and EU policy, Local Agenda 21 movement)
- *Financial drivers* (e.g. 1970s oil crisis, high energy bills and desire to reduce them)
- *Knowledge drivers* (e.g. a lack of know-how, influence of previous research programmes)
- *Market drivers* (e.g. existing or expected market demand)
- *Health & comfort drivers* (e.g. living in healthy homes)
- *Design drivers* (e.g. aesthetics, desired space)

*Environmental drivers* were evident in the majority of the cases (n=21), including cases initiated by individuals who had strong green values and were motivated by environmental concerns and climate change or aiming to pioneer in low carbon buildings. Interestingly, quite a few cases originated back to eco-oriented societal movements and sustainable housing activists in the 1970s, and a total of 20 cases had what we classified as *eco-social drivers*. These also included drivers such as the desire to enable alternative lifestyles, create communal living, follow the principles of sustainable development and provide fair housing.

In 13 out of 25 cases, *policy* was one of the drivers in the form of influence from international, national and local policy measures. The articles mentioned the Kyoto Protocol, EU level decisions, national policy agendas and Local Agenda 21 as policies driving innovation. Moreover, Quitzau et al. (2012) mentioned a gap between policy intention and policy implementation as a key driver for one project. If policy actors are included in the analysis, eighty percent of the cases had some favourable support from public authorities or policy. In 13 out of 25 cases, local authorities had a significant influence either through supportive individuals within the local authority (n=5); municipal housing fund acting as the key actor (n=6), municipal eco- and energy requirements for new buildings within district area planning (n=1) and land sold to a non-highest but energy efficiency oriented bidder by the local council (n=1) – in only one of these cases a specific policy instrument acted as a driver. Equally in 13 out of 25 cases, national policy was influential, only six cases (all based in Ljubljana, Slovenia) combining local and national influence. In majority of cases a mix of policies played a role ranging from RD&D and deployment subsidies through innovative competitions to building codes and planning regulations. Building regulations have clearly been important (n=11), while equally over a half of the cases have been initiated without the guiding influence of building regulations. Policy changes *during* the innovation processes have also influenced, for example, energy efficiency subsidies running out during a budget year delaying one project with a year, or a project initially beginning without policy influence having to alter its optimal design type due to the introduction of new building requirements (Pässilä et al., 2015)

In 12 out of 25 cases one of the initiating factors was *financial*, largely driven by high energy bills and the desire to reduce energy costs. For example, in six cases, there was a clear motive to provide lower energy bills for social housing tenants to ensure that they were able to pay their rents and hence secure income for the social housing landlord (Broto, 2012). In four cases, *knowledge drivers* were identified, including cases where existing knowledge played a key role (e.g. a planning team with high capacity and previous research programmes' findings on energy efficient buildings) and cases that were driven by lack of knowledge (e.g. lack of know-how of energy efficient building and lack of innovativeness in the housing industry). *Health & comfort drivers* were evident in two cases: one architect-owner aspired to create a healthy home as his child had asthma (Mlecnik, 2010), while in another case one of the key motives was to create not only energy efficient houses but also healthy living environments (Jensen and Gram-Hanssen, 2008). Similarly *market drivers* were identified in two cases, one experiencing (niche) market demand for passive houses and in another the company aimed to be a frontrunner expecting future market demand (Mlecnik, 2010; Pässilä et al., 2015). Finally, *design* features were evident as a driver in two cases, including the desire to have not only sustainable but also aesthetically pleasing housing in one case, and the desire to create a better space for living in another (Mlecnik, 2010; Pässilä et al., 2015). The analysis shows that while there was a range of drivers identified for the cases, environmental, eco-social, policy and financial drivers featured most often, while knowledge, market, health & comfort and design were less evident.

## 4.2 Roles, functions & activities of intermediaries

Intermediary actors were explicitly mentioned in relation to four case studies, while our analysis identified that intermediary actors were in effect involved in 14 out of 25 cases. This does not necessarily mean that there were no such actors involved in the other cases, as findings only reflect

the style in which the cases were written. Particularly the eco-village developments appear rather independent with little influence from intermediary actors (Smith, 2007; Lovell, 2008; Holm et al., 2011). Intermediary actors represent 10 different organisations, five operating locally and five nationally. Five types are represented: local authority agents, business network organisations (trade bodies), independent groups/foundations, a public housing fund, and a government energy efficiency agency.

In nearly half of the cases local authorities seem to be key players in the low energy housing innovation processes, including local authority's energy manager (Lovell, 2008), municipal planners (Quitau et al., 2012) and a public housing fund (Broto, 2012). When local authority agents have acted as intermediaries, they have (1) *facilitated concrete building projects* by connecting actors (networking), speeding up planning and permitting processes (learning) while also aiming to influence local politicians (articulating expectations) (e.g. Lovell, 2007); (2) *aimed to create niche markets* for new low energy housing innovations through developing planning policies and building requirements in exemplary districts (articulating expectations), searching for new technological and policy designs suited to these districts (learning) and bringing together entrepreneurs and constructing companies (networking) to showcase these innovations (articulating expectations) (e.g. Holm et al., 2011; Quitau, 2012); and (3) *implemented new practices in publically owned building stock by showcasing developments* based on a vision of a pioneer low carbon city (articulating expectations), bringing together land, knowledge and financial resources and creating new partnerships to realise these developments (networking), and learning from the practices and adoption of new technologies by tenants (learning) (Broto, 2012).

Interestingly in other contexts, other (intermediary) actors have taken similar roles to those described above. For example, an independent Local Agenda 21 group facilitated a similar market creation process in Herfølge, Denmark, as the local authority had taken in Stenløse Syd, Denmark (Holm et al., 2011). Other actors, such as a government-owned energy-efficiency company or a foundation, have supported processes to create new business models for low energy housing by organising competitions for new housing designs (articulating visions), connecting actors such as architects, house buildings and buyers (networking), and managing these processes including information dissemination, knowledge building and adjusting goals (learning) (Heiskanen and Lovio, 2010; Pässilä et al., 2015). These kinds of actors are important in as that they can reach a geographically wider scope and are less dependent on (local) values, politics and interests. In only two cases business network organisations were described to take intermediary roles (Pan and Cooper, 2011; Mlecnik, 2013). In Belgium, a passive house platform performed a range of activities, including articulating opportunities for companies and demonstrating passive house designs (articulating expectations), providing opportunities for partnering, aiding in finding and applying for resources, brokering negotiations with project partners (networking) and organising visits and workshops (learning) (Mlecnik, 2013).

## 5. Conclusions

Our systemic review of case studies on low energy housing innovations demonstrates that scholarly research on this topic is limited. Particularly innovation studies on low energy in the context of existing building stock barely exist with the exception of two articles. This, thus,



demonstrates a need to qualitatively explore the processes, drivers and barriers to innovations, and intermediary actors, in whole house retrofits. The review shows that a local authority or national policy were supportive elements in over a half of the cases. National policy particularly influences through building regulations but also RD&D subsidies. Building regulations have been important, especially as they have usually been repeatedly tightened, sometimes altering project goals, if changing during the innovation process. This indicates that not only the existence of supportive policies but their dynamics with innovation is crucial, calling for further research. Besides policy, generically environmental concerns and eco-social values have been key drivers for these developments. In addition, financial drivers, including increasing energy prices and the opportunity to cut bills, have played a major role. Knowledge, market, health and comfort, and design drivers were surprisingly rare as drivers in the studied innovation processes. This may indicate that a lack of a more holistic picture, i.e. system or architectural innovation, can be the outcome when drivers are such that limit focus to a particular aspect of the environment – such as energy – or immediate financial savings. Improved focus on the synergies between energy efficiency, health, comfort and design could lead to more systemic innovation in the sector.

Equally to public policy influence, intermediary actors were present in over half of the cases. In most cases a local authority agent (1) facilitated a construction process, (2) aimed to create a market for new technological solutions, or (3) implemented new technological designs through social housing stock. Only in a few cases other types of intermediaries, such as independent organisations, independent foundations or network platforms of businesses were shown to play a role. This calls for more specific studies focusing on the range of intermediary actors that take part in different phases of the innovation process. This includes also the identification of crucial intermediary functions in both supporting the emergence of innovation niches and the expansion or empowering of those niches within/to the socio-technical building regime.

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# A smart future housing in Egypt for all- a challenge or an opportunity?

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## Abstract

Egypt's population has recently reached 90 Million inhabitants. A figure that is expected to double in the coming 20-30 years. With around 60% of the population less than 30 years old and the anticipation of demographic change; Egypt should be prepared to accommodate the various needs. Nevertheless, the current built environment in Egypt does not seem to accommodate people's current socio-economic needs; and no plans are evident that the anticipated demographic change is taken into consideration.

This paper is part of an ongoing research project<sup>1</sup> to investigate current built environment challenges and opportunities in Egypt, with particular emphasis on housing. Literature review, supported by an exploratory case study, was adopted to define current challenges and potentials, in an attempt to define ingredients needed for a smart future housing for all. An informal area was selected for the case study to demonstrate the functional interventions by individuals to fulfil their day-to-day needs.

For 60 years now, public housing in Egypt has always adopted a top-down approach. However, housing supply by the Government and private sector combined, to date, is failing to meet market housing demand. The consequences of which are illegal informal developments and/or illegal transformation of the original 'formal' developments. This would not only burden the infrastructure and consequently affect people's physical health, but may also elevate psychological distress and aggression. Nevertheless, despite the negative impacts, informal developments' interventions seem to, unintentionally, bear basic principles of universal design such as multi-use of residential spaces and mixed-use buildings. Hence, could be considered 'smart'. A building does not necessarily require sophisticated technologies to be 'smart' as long as it adapts to people's current and future needs. Therefore, there is an opportunity to achieve smart housing for all, if current informal interventions could be capitalised on and deployed properly and legitimately in housing projects.

**Keywords:** Adaptability, demographic change, Egypt, smart housing, universal design,

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# 1. Background

In light of the rapid change and transformation of social, political, economic aspects, in addition to the technological advancement; urban planning approaches and techniques should cope with and govern the unprecedented pace of change in the Egyptian society. Hence, the call for smart urban planning (reinventing planning, 2006) to prevent chaotic developments to take over formal planning.

Egypt population density is reported to be 1,066 per km<sup>2</sup>; whereas in Cairo, the capital, the density exceeds 46,000 per km<sup>2</sup>. With the increased number of population in Egypt, currently more than 90 Million, the Government is being challenged to alleviate a complex problem that has never been resolved since the 1950s; namely the provision of housing that is affordable, and yet adapts to people's various needs.

While there is no official figure confirming the number of housing units needed annually, it is argued that at least 300,000 units are needed (Real Estate, 2012). In comparison to the UK, housing market demand is estimated around 232,000 – 300,000 units/year (Gorgolewski, 2003; Barlow et al., 2002; Parliament, 2015). However, considering cultural, social, and demographic variations among Egypt and the UK; the estimated annual need of 300,000 units in Egypt do not seem to be a relevant figure. Even if this anticipated figure was true, Egypt is far from being able to meet this market demand. According to CAPMAS (2015) housing units achieved in the year 2013/14, by both public and private sectors, account for around 146,000 units in comparison to 136,000 units back in 2012/13 which is less than half of the estimated need. The distribution of the supplied units includes 55% economic housing; whereas low cost housing was only 3.2%. Nevertheless, the definition of low cost and economic housing is not clear in the CAPMAS report.

In Greater Cairo, according to Colliers (2015), an average of 90,000 – 100,000 units are required annually to meet the demand generated by new households. Though, it was recorded that only 45,000 units enter the market every year, i.e. only half of what is required could barely be met. Thus, suggesting the already existing gap to amount to 6 Million households and the annual demand to rise to 500,000 units by 2020 (Figure 1).

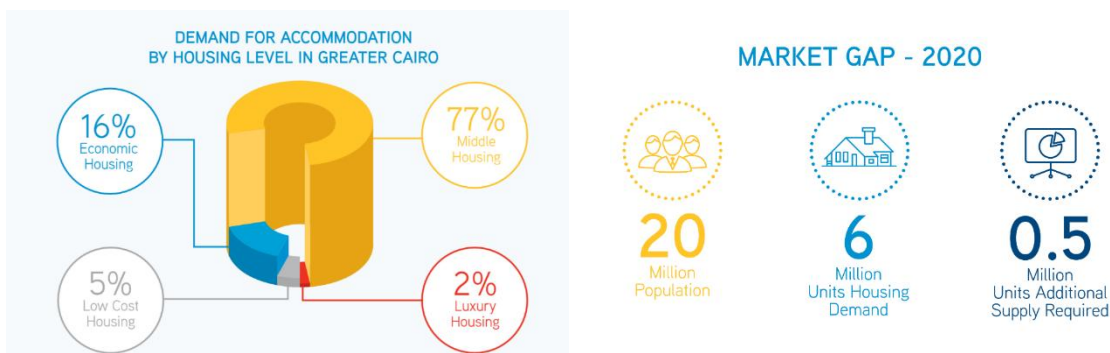


Figure 1: Demand for accommodation by housing level in greater Cairo (Colliers, 2015)

The persistent inability of successive Governments to meet housing demand may have arguably resulted in the unprecedented pace of informal developments continuously taking place.

## **2. Housing challenges in Egypt**

The main focus of extant literature over the past decades was, to a large extent, mainly concerned with the affordability of units and financial capabilities of households (which undoubtedly is very important). There is, however, no clear evidence on investigating the reciprocal effect of the built environment, in general and informal developments in particular, with regards to not only the physical but also the psychological health of Egyptians, the anticipated demographic change, and impaired mobility.

### **2.1 Chaotic development and impact on health**

Due to the inability of successive Governments to meet housing demand and further provide affordable and adaptable housing; individual chaotic interventions has taken over planned development throughout the past 60 years to date. Chaos is manifested in residential buildings being built illegally and informally in any space available with no attention to regulation, to building codes, nor to health and safety measures. The illegal construction is arguably spreading at a pace unprecedented in the past five years (Nadim et al., 2014). The ramification of this blatant infringement of public spaces, the crowding, and poor environmental conditions in housing projects are serious implications not only on the physical but also on the mental health of individuals. No empirical studies could be identified within the Egyptian context; however, several international literatures investigated the association of built environments with mental health (Evans, 2003; Guite et al., 2006). According to Evans (2003) for example, the number of people per room, and noise may elevate psychological distress, hypertension, high blood pressure, heart disease, hearing impairment, stress levels, reduced ability on concentration, and disturbed sleep (Stansfeld and Matheson, 2003). Furthermore, malodorous air pollutants intensify negative impact; and some toxins (e.g. lead and solvents) may cause behavioural disorders such as self-regulatory ability and aggression (Stansfeld and Matheson, 2003; Evans, 2003). Notwithstanding these issues, Evans (2003) argues that insufficient daylight is strongly associated with increased depressive symptoms. This is further supported by Guite et al. (2006) who confirmed the association between the physical environment and mental well-being attributing the important negative impacts to noise, sense of over-crowding at home and in open spaces, in addition to fear of crime.

### **2.2 Demographic change and impaired mobility**

The population growth rate in Egypt has been decreasing since the period 1980-1985, where it stood at 2.28 per cent. Then it reached 1.56 per cent in the period 1995-2000 and slightly increased afterwards to 1.68 per cent in the period 2005-2010. Currently, the growth rate is being reported at around 2%. However, this is expected to decline to reach 1.4% in the period 2020-2025 and reaches 1.1% in 2045-2050 (UN, 2015). Furthermore, the proportion of the elderly population (65+) has been increasing and was estimated to be 5.9% in 2015 and anticipated to double to reach 12.3% by 2050 suggesting a demographic change (Figure 2). However, according to CPAMAS (2015), the percentage in 2015 has already reached 6.9% (6 Million people equally distributed among both genders), i.e. is 1% more than estimated. In the same context, UNFPA (2015)

demographic report concluded that Egypt should get prepared to deal with an aging population and the consequent increase in the dependency ratio.

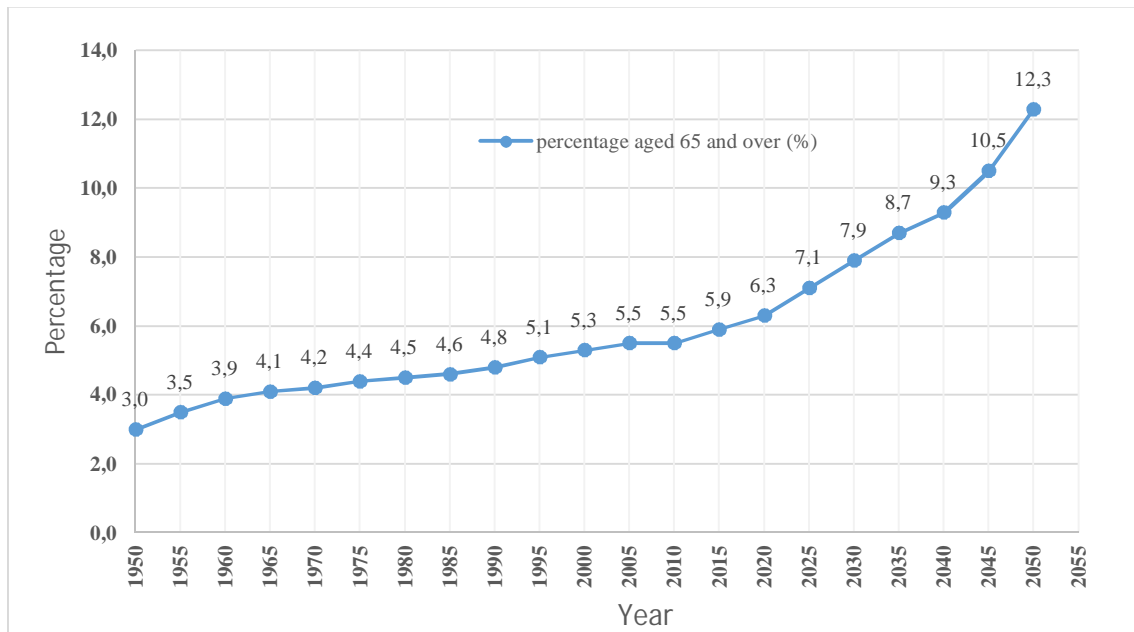


Figure 2: Trend of Egypt's Elderly Population, 1950-2050 (UN, 2015)

In addition to the increased number of elderly (CAPMAS,2015), another 7% of the population - amounting to around 6 million - have some sort of impairment CAPMAS (2006). Thus, there is a considerable percentage of Egyptians who are not taken into consideration when planning and designing the built environment. These, currently, underprivileged segments of the society, are not the only ones suffering, but their families and friends as well; a figure that could easily impact 20 Million people who may have relatives or friends not being able to move around freely, neither indoors or outdoors.

The Egyptian built environment in general arguably needs houses, neighbourhoods, and whole communities to accommodate all abilities across the lifespan. This requires better planning and arrangement of uses, streets, paths, public spaces, and transportation systems (Nasar and Evans-Cowley, 2007). The impairment law in Egypt (chapter five, clause 27 and 28) requires that all new builds and open spaces, in addition to the existing environment, to be adjusted to be friendly to people with all different impairments. Furthermore, 5% of the subsidised housing is set to be made available for those with different abilities. Nevertheless, no real evidence on ground could be recorded with regards to adjusting current and/or new build.

While in Egypt there is no evidence of any proactive measures to deal with the aging population, the developed world is being very active in this respect. In the UK, for example, and as a response to the demographic change, a policy goal has been put to meet the housing needs of an ageing society. In this context, the UK regards population aging as an opportunity rather than a threat as

it is anticipated to boost the social, civic, and economic capital of the community (ILC, 2008). Furthermore, the US consider the future design, structure, and function of their housing, neighbourhoods, and communities as a central issue to an aging population. The strategy is therefore to develop healthy communities that would engage everyone and foster intergenerational experiences (Cisneros et al., 2012). One of the innovations suggested for older people who wish to continue working in a small, self-employed setting is the live-work concept (Kallash and Kruse, 2012); where the dwelling would include a workspace. Suggesting that mixed uses create settings where older people can comfortably pursue careers (Cisneros et al., 2012).

According to the World Health Organisation (WHO) an age friendly city is 'friendly for all ages' and not just 'elderly-friendly'. It should be clean, have well-maintained (green) spaces with adequate toilet facilities, pedestrian-friendly walkways, outdoor seating, smooth well-maintained pavements, sufficient pedestrian crossings and street lighting, etc. (Smedley, 2015). It is argued that making homes and the environment safe for the elderly would arguable make them safer for the younger people as well (Cisneros et al., 2012).

### **3. Universal design and smart buildings**

Universal design is a concept aimed to make daily functioning easy for the general population. The key principles to universal design can be categorised under equitable use, flexibility in use, simple and intuitive products, tolerance of error, low physical effort, and size and space (Cisneros, 2012). These may be further interpreted to address accessibility, visibility, functionality, and movement in a space (Figure 3). Another important term associated with 'universal design' is 'visitability'; a movement, that investigates components and minimum features and standards to make buildings accessible to people with mobility impairment (Cisneros, 2012) such as:

- open floor plans, i.e. minimising subdivisions,
- reducing number of hallways,
- making rooms more open to accommodate a variety of abilities.
- a front door to accommodate a wheelchair
- a sink with a knee space for independent use of the kitchen
- plenty of under cabinet and task lighting,
- accessible lighting outlets, and electrical switches
- front-loading washing machines
- bathroom accessible shower design



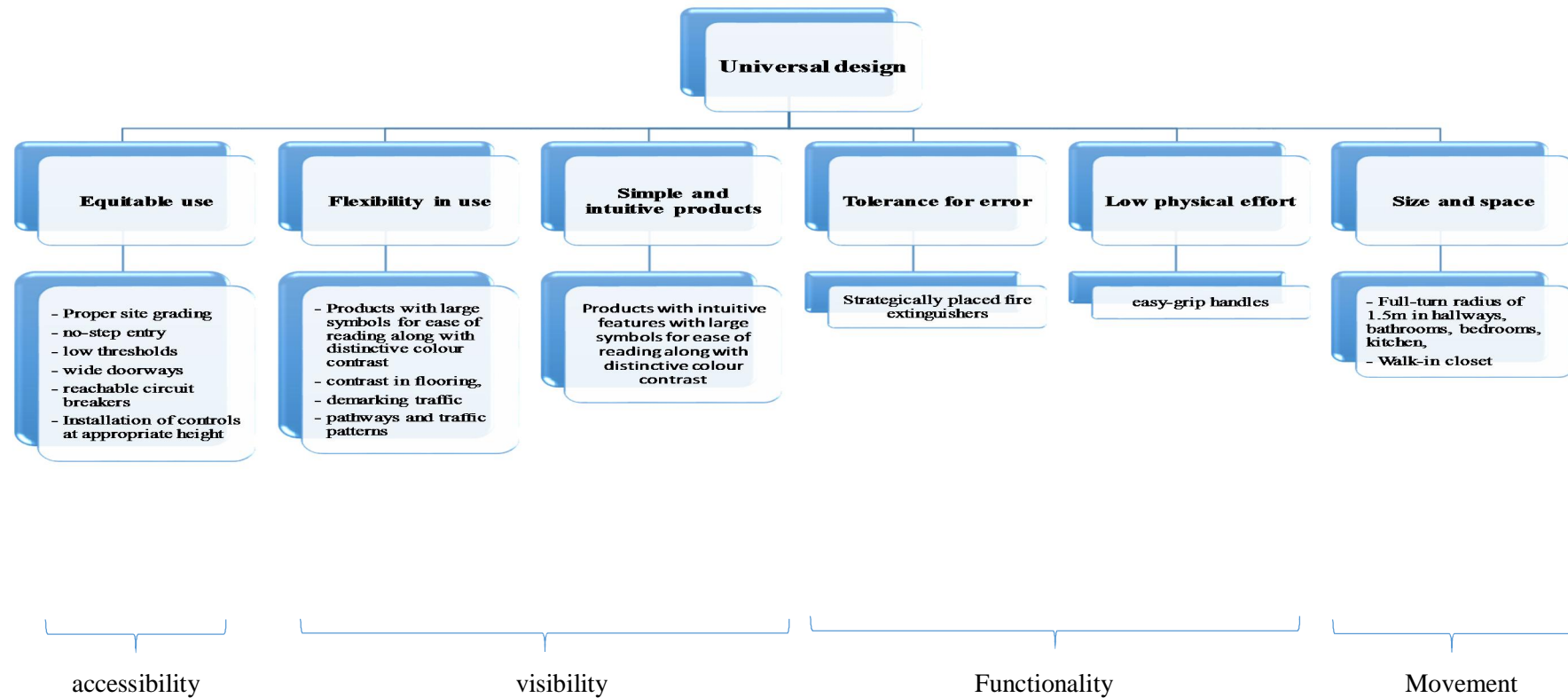


Figure 3: Universal Design principles (adapted from Cisneros, 2012)

## **4. Informal housing in Egypt – The exploratory case study**

This exploratory study investigates an informal area in Greater Cairo in order to define major dwelling and the immediate surroundings concerns, and the respective interventions to accommodate basic needs. The reason for selecting an informal area, is that informal areas represent two thirds of Greater Cairo's built environment; hence, may be considered a representative exemplar for pure functional solutions to people's everyday needs. The investigation took a form of semi-structured meetings, to define, in depth, people's perceptions with regards to the area they live in, in general, with particular emphasis on their dwellings and the immediate surroundings. The aim was to have various age groups and different physical abilities. An announcement of the meetings was made through an active NGO in the area, and the participants are those who voluntarily joined the meetings. In total, four groups were represented, the elderly (6, three with severe joint problems), youth (4), university students (4), and contractors (2). The meetings aimed to conclude dwelling spatial organisation (plan) and the various associated functions, the vertical circulation (entrances, stairs, and roofs), and any informal transformation that took place on ground floors.

The informal area, under investigation, encompasses both residential blocks built by the Government back in the 1970's and informal buildings that are being built to date. It is an old area and was originally an agricultural land with a few houses; which along the years, gradually became an informal urban settlement with multi-storey buildings, and the agricultural area eventually disappeared (GIZ, 2013). The Family average size is six including both parents; where women largely work in various jobs to contribute to family income (GIZ, 2013). A study published by an NGO in the area, while not confirming the number of people with impaired mobility in the area, concluded that 72% of people with some kind of impairment are illiterate, and only 6% managed to get higher education. Unemployment rate, furthermore, reached 87% arguing that current local work market is 'repelling' 1/3 of the people with some kind of impairment (Abdelbaki, 2015).

The Government built blocks' areas range between 60-70m<sup>2</sup> including two to three rooms, constituting of a ground floor and four typical floors. Informal buildings, however, provide a bigger range of areas in order to accommodate the different financial abilities. There are those that may exceed 100 m<sup>2</sup> and those even smaller than 40m<sup>2</sup>. Some of these informal buildings may have 12 typical floors. As a result of the relatively small unit areas and the large number of family members; spaces are used for multi-functions particularly the reception/entrance, children bedrooms, and even the corridors/halls (Figure 4).

### **4.1 The residential unit**

Egyptian families are generally conservative, therefore a complete separation between family private spaces and spaces to receive guests has to be achieved in the unit. In some cases, areas to receive guests are never used by family members to keep them in good condition. There is no clear pattern between the different participants with regards to the multi-use of spaces. In some cases, the entrance may be used for eating, receiving guests, watching TV, and even studying. The hall/corridor may house the washing machine, storage spaces, and the fridge. Furthermore, the children bedroom may be used as a family living space and a reception for close relatives. The kitchen and toilets are relatively small to accommodate any other activities. There was a case where cooking could take place in the main bedroom; however, in most cases main bedrooms are not used for any other functions. In general, the

type of functions used depends on the size of the individual rooms as well as the overall dwelling area, i.e. depends on the financial capabilities of households.

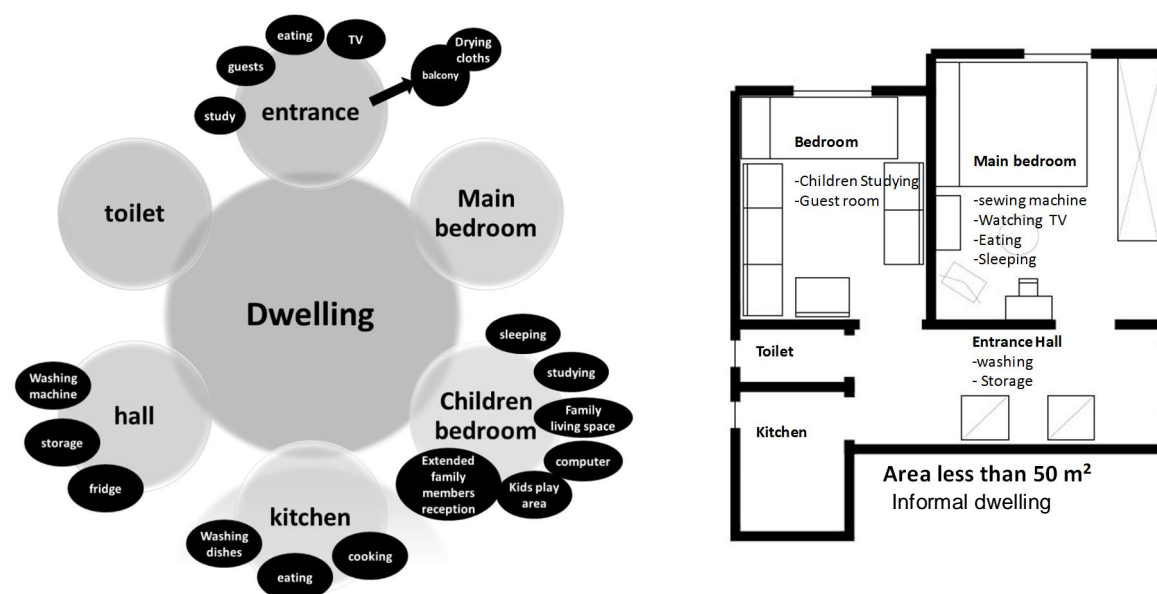


Figure 4: Dwelling spaces various multi-uses to accommodate every day needs in small areas

## 4.2 Mixed-use transformation/ developments

Another prominent feature in informal developments, is the transformation of primarily ground floors in Government built buildings into other non-residential activities, whether these are commercial, industrial, or even raising livestock. The informal buildings on the other hand, include a four-meter-high ground floor reserved for non-residential activities from the outset. This, while is intended for generating income and employment, is perhaps more importantly intended for raising the first residential unit at least four meters above the street level for not to be accessible from the street level for security reasons. In addition, the building entrance is raised one meter above street level, to ensure that when Government pave streets, the entrance would not ‘sink’ below street level. This is intended to protect the building entrance from sewage overflow that is common in the area. Nevertheless, the increasing number of steps at the entrance, puts further burden on the elderly, and those with impaired mobility; especially that the riser could be as high as 50cm. The roofs in general, are used for ditching scraps, and in very limited cases are used for raising chicken or sheep, or planting vegetables.

These non-residential activities (largely on ground floors), while generating income to owners and create jobs; they nevertheless, burden the infra-structure such as water, sewer, and congest streets etc. In addition, the different activities may result in bad odour due to the different industrial and/or organic waste. Nevertheless, the majority of participants did not mind non-residential activities on the ground floor, as long as it did not harm the residents wellbeing and comfort, and did not cause higher rental fees for residents.

## 5. Discussion

Egypt has always been challenged by the provision of affordable housing; while seeming to overlook, or neglect the provision of adaptable housing that would respond to various socio-economic needs for the past 60 years. In addition, it is not evident that plans are set to accommodate anticipated demographic change and the increased dependency ratio.

While housing provided by the Government promote complete functional separation of uses; informal interventions are largely based on mixing residential and non-residential functions. Despite the negative impact on infra-structure and people's physical and mental wellbeing (section 2.1), benefits could also be recorded. Mixed-uses may have the benefits of enabling people with a range of incomes and backgrounds to reside side by side; and thus, help foster greater social equity and integration (Friedman, 2012). In addition, building homes for seniors along with dwellings for young households may further attract extended families and create a mutual support system. Notwithstanding this, design approaches adapting to changing demographics and lifestyles arguably include live-work dwellings, support aging in place, and multigenerational, small size, and adaptable housing (Friedman, 2012).

In light of the above, an important question should be raised, namely: are smart buildings exclusive to developed countries; or could buildings still be 'smart' with less or no sophisticated technology? Before attempting to answer this question two terms are investigated, namely 'smart building' and 'technology'.

Smart building, is usually referring to a building being intelligent i.e. it encompasses various technologies, such as data network, voice network, power management, video surveillance, fire alarm, HVAC control, lighting control, access control etc. with the different systems having the capability to communicate for a much efficient use of the building (Sinopoli, 2006). Other interpretation of smart building may encompass (although still associated with the integrated systems) responsive and adaptive envelopes and material that respond to the internal and external environment, green roofs, inclusion of Photo Voltaic, etc. It is, however, important to investigate the extent to which homes could be smart, without the inclusion of sophisticated technologies (Friedman, 2012). This is of particular importance to developing countries.

'Smart', as an adjective, is usually associated with either intelligent people or a technology that is intelligent i.e. responds to the end users' needs and make their experience as efficient as possible. The term 'technology' may refer to a new product and/or a process (Laborde and Sanvido, 1994). In this context, it can be argued that a 'design' may refer to a product (if it is noun) or to a process (if it is a verb); and in both cases a 'design' is associated with a new 'creation'. Therefore, a design may be considered a 'technology' that could be 'smart', as long as it is able to respond and adapt to current as well as to future dwellers' needs. Since, universal design principles aim at a design that could be easily adapted to current as well as to future needs, accommodating all ages and mobility; it could result in 'smart' buildings. Thus, it could be concluded that 'smart' buildings could be achieved by simply achieving a universal design; and not necessarily to encompass sophisticated technologies.

## 6. Conclusion

Egypt is currently facing huge housing challenges to solve a problem that successive Government failed to solve for the past 60 years. Currently, with more than 90 Million inhabitants, and around 300,000 housing units needed annually, the anticipated 6 Million gap in housing provision by 2020, and the expected demographic change; the housing problem seem to exacerbate due to the multi-variate complexity. The inability to provide affordable and adaptable housing, has led to individual chaotic developments that do not pay attention to or abide by building codes and regulations. This may lead to physical as well as mental/psychological implications.

This paper investigated the housing challenge in Egypt, and the implication of informal developments on people's health and well-being. The paper acknowledges the importance of informal developments to satisfy socio-economic needs; but also highlighted the negative impacts of such informal chaotic development. However, it was concluded, that despite the negative implications of informal developments, they imply some sort of 'smartness', particularly that these depend on the provision of mixed-uses, include extended families, are small in size, and allow adaptability of spaces.

In conclusion, there is an opportunity to provide a smart future housing in Egypt by mitigating negative challenges of informal developments and capitalise on the positive. The result of this paper will feed into the second phase of the research to provide scenarios for future housing that takes into account the socio-economic, demographic change, as well as technological advancements.

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# **Regional Energy Model -Based Approach to Identify New Business Opportunities While Increasing Energy Efficiency**

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## **Abstract**

The importance of reduction of energy use in tackling climate change is widely recognized. The greenhouse gas (GHG) emissions of energy production are high, while the biggest share of energy consumption belongs to the built environment and industry. Various regulations and treaties create pressure for reducing GHG emissions on both regional and national level.

The energy sector provides significant potential for tackling climate change. However, achieving the goals will require changing the traditional energy systems of the society. Here, introduction of renewable energy sources, as well as increasing the efficiency of energy production, transmission and consumption, are needed. Major changes in regional energy systems are most likely to occur in the near future, an important one being the increasing of self-production of energy, where actors traditionally considered as consumers of energy will become also producers. The upcoming changes will create challenges for decision-making related to the development of energy systems, as traditional approaches will become insufficient to operate under the new conditions. The changed patterns of regional energy systems also create new business opportunities, and the recognition of them is important to integrate into the decision-making processes in order to support sustainable development of the energy system in the region.

This study proposes a regional energy model -based approach to identify new business opportunities in changing conditions and to support sustainable development of the energy system. The framework of the approach requires modelling the current state of the energy system of particular region. This includes identification of the different actors within the energy system and the energy flows between them. Such an approach makes it possible to compare different future development scenarios and evaluate them in terms of environmental, economic and other targets. The approach can help the different actors within the energy system (energy production, industry, buildings, services, etc.) to develop their operations by providing them with holistic information on the current state of the energy system, possible development paths, future energy demands, realization of sustainability targets, as well as emerging new business opportunities.

**Keywords:** Energy efficiency, Regional model, Business opportunities, Decision-making

# 1. Introduction

The role of energy use in tackling climate change is widely recognized as extremely important due to the high greenhouse gas (GHG) emissions of energy production. The energy consumption of the built environment and industry is high. These sectors are responsible for 96% of energy end-use and 86% of GHG emissions in Finland (Sitra 2010). Emerging regulations and treaties create pressures for reducing GHG emissions on both regional and national level by posing emission reduction, energy efficiency and other targets. Economic issues are often the major challenge in achieving the required GHG reductions.

The energy sector provides great potential for tackling climate change. However, achieving the targets requires changing the traditional energy systems of the society. During the urbanization and industrialization period, energy production solutions concentrated on large centralized fossil fuel based production units. The increased pressure to achieve a low-carbon society and energy self-sufficiency requires transition from fossil fuels towards local renewable energy sources (Motiva, 2010). Also increase of energy efficiency in the processes of energy production, transition and consumption, is required (Saidur, 2010; Abdelaziz et al., 2011; IEA, 2012). One important change will come due to increase of the decentralized self-production of energy. This change is in Finland driven by such factors as fast technological development and new building codes, which support the utilization of locally produced renewables (Ministry of Justice, Finland, 2011). This means that traditional energy consumers such as households or private companies, can become producers (Nielsen & Moller, 2012; Li, et al., 2013). Such a change can result in a decrease of the demand for centrally produced energy (Persson & Werner 2011). The changing energy system will create challenges for future energy planning, as traditional approaches will become insufficient. However new business opportunities would also emerge, and it is important to integrate the recognition of these into the decision-making in order to support sustainable development of the energy system of the region (Viholainen, et al., 2016). Therefore, the creation of simple methodologies to provide information on sustainability of the current state and optional development scenarios of the regional energy system is required.

This paper presents an approach for including sustainability aspects systematically in the decision-making process related to the development of a regional energy system while paying attention to the local conditions of the region in question. The approach is based on the recognition of individual functional characteristics of the energy system of the region and identification of the mechanisms affecting the realization of regional sustainability targets. This includes charting the regional energy system by identification of the actors (centralized producers, transition network operators, consumers and prosumers), as well as the roles and interests of the actors, the pattern of energy flows within the system, and the mechanisms affecting the energy-related decision-making of the actors. Finnish conditions are used as an example.

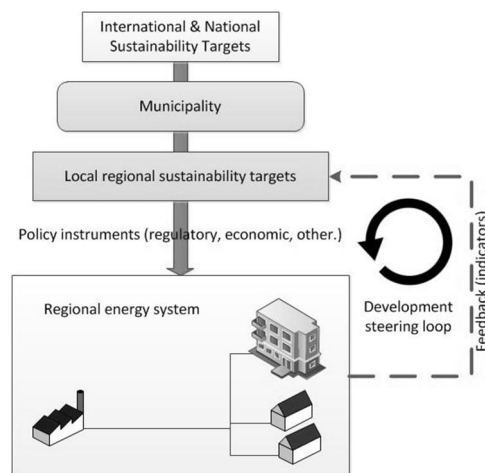
# 2. Methodology

The municipality is the only permanent operator within the regional energy system, and it plays the role of the upholder in the region. The primary responsibility of the development of the



regional energy system, as well as the realization of international and national sustainability targets lies on the municipal administration. International and national sustainability targets create pressure for the municipal administration in the form of legislative norms and binding targets. In order to achieve the sustainability targets in the most efficient way, municipal decision-making should incorporate a comprehensive analysis of local region-specific conditions, including economic, environmental and social aspects. Knowing the potential and challenges of sustainability within the region helps the municipality to establish a local sustainability policy and targets that would drive the development of the energy system while supporting the realization of international and national targets. Establishing an adequate local sustainability policy and targets forms a solid base for sustainable development of the regional energy system.

The municipal administration controls the development of the energy system towards the chosen sustainability targets by applying various policy instruments, which can be regulatory, economic or some other instruments. To understand which policy instrument would be the most efficient one to achieve the sustainability targets, the impact of various regulatory actions on the energy system and the targets should be evaluated thoroughly and transparently (see Figure 1). Here we can consider the municipal administration as a supervisor of the process (development of the regional energy system) sending control inputs (regulatory and economic policy instruments) into the system while receiving surveillance feedback (indicator data) from the system and comparing the indicator data with the parameters required by the local sustainability policy. The appropriate indicators should be selected carefully to provide the required specific information on the performance of the energy system. The sustainability indicators should be chosen according to region-specific conditions, but should cover economic, environmental and social aspects as well.



*Figure 1: Steering of the development of the regional energy system*

The evaluation process described above requires good understanding of the energy system in question. In order to understand the current situation of the energy system and to be able to predict the further development of the system, it is essential to recognize issues like the mechanisms that affect the formation of heat energy demand, how energy demand affects energy production, what influence different scenarios have on the sustainability indicators, and with what kind of mechanisms the municipality can steer the development. It is necessary to map the different actors

operating within the energy system, as well as the energy flows between the actors. The roles and interests of the different actors and the issues affecting the energy related decision-making of the actors should be recognized. This will help to incorporate the interests of the different actors in the decision-making process, creating better operating conditions and helping with the realization of new business opportunities under the changing circumstances. The information required for mapping the local energy system can be gathered by various means, such as collecting data from the actors, energy modelling of different processes within the energy system, etc.

### **3. Regional sustainability approach**

In this study, a common approach for systematical steering of the development of the energy system towards international, national and local sustainability targets is developed. The common framework for the incorporation of sustainability issues into the development process of a regional energy system is presented in Figure 2. The approach starts with the identification of the regional sustainability policy established by the municipality based on national and international treaties, the legislative framework and local conditions within the region. The regional sustainability policy incorporates environmental, social and economic targets for the future development of the region in question. These targets should be identified clearly from the very beginning of the decision-making process.

The second step in the approach is charting the functioning of the regional energy system. This starts with identification of the actors (centralized producers, distribution network operators, consumers and prosumers) operating within the chosen region, as well as the pattern of energy flows between the identified actors. Also issues affecting the energy-related decision-making of these actors, such as economic interests, preferences etc., need to be identified. The municipality can be considered as one of the actors, as it regulates the development of the energy system. The common pattern of the regional energy system, including the roles of different actors is presented in Figure 2 below.

The next important step is the recognition of indicators (key measures) that would help to estimate the actual development of the energy system towards the regional sustainability policy and targets. Each actor within the energy system is important for contributing on their own behalf to regional sustainability, so appropriate indicators should be identified for each class of actors. The indicators should incorporate at least environmental, economic and social issues. Also other local policy-specific indicators can be included in the approach. All indicators should be selected on a case-specific basis in order to illustrate the particular local sustainability targets in the best possible manner. Studying the functioning of the local energy system will help the decision-makers to understand how energy demand is formed, what mechanisms affect the formation of energy demand, how energy production and transition is affected by changes in the energy demand, and how these issues affect the sustainability indicators.

The presented approach makes it possible to evaluate different possible energy system development scenarios in terms of sustainability targets. Based on regulatory input and sustainability indicator output analysis, optimal steering instruments can be chosen that will

support the development of the regional energy system towards the realization of local sustainability targets. Including the regional sustainability approach in the process of regional development would help to incorporate the interests of the different actors in the energy system into decision-making. Also challenges and new emerging business opportunities can be recognized and taken into account while steering the local development towards sustainability.

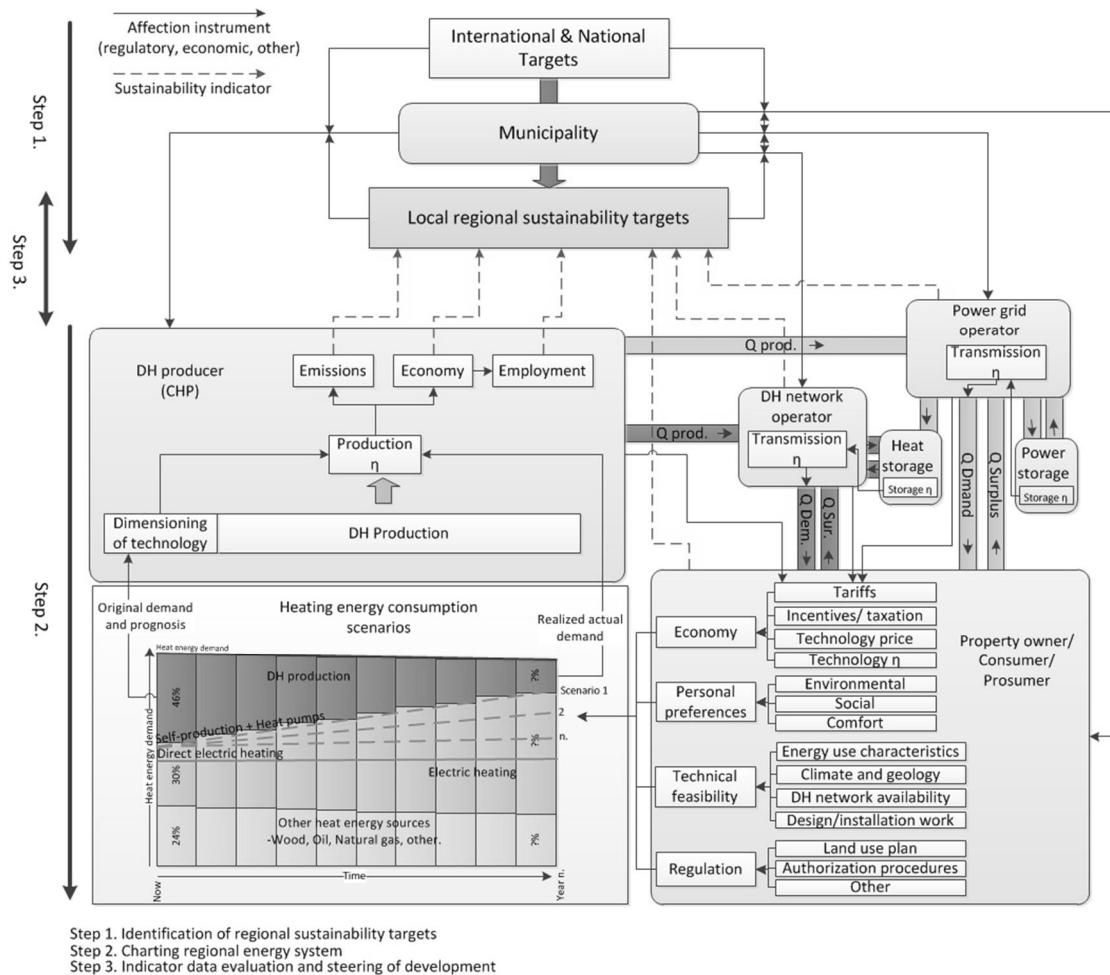


Figure 2: Regional sustainability approach

### 3.1 Charting of the regional energy system

#### 3.1.1 Consumer or prosumer

The consumer is the operator of a building of a particular purpose. Buildings, in turn, are where the energy demand for the region is formed. The operators and the purpose of the buildings vary, as the buildings can be domestic, commercial, industrial, or municipal. Traditionally, building operators have been considered as energy consumers, but due to technological development and economic factors, self-production of energy is increasing. Self-produced energy is either used on site to cover the energy demand of the operator, or it can be sold to the regional energy distribution operator. Within the energy system, these actors can no more be considered traditional consumers due to changed role and interests, but are rather a so called prosumers. The impact of increasing

self-production and prosumers on future energy demand can be major. The main interest of the energy consumer is to cover the required heat and power demand with the cheapest possible energy, while prosumers are interested in getting a maximal price for the energy sold to the distributors. Also both consumers and prosumers wish the energy services to be provided reliably and with minimal effort.

Selecting the heating method is a big decision the operator of the building has to make. In addition, the operator can decide whether to self-produce energy on site and to what extent, and whether to sell the energy or not. For the operator these decisions have a long-lasting effect, since the chosen technology will be in use for decades. The decision-making is driven by such factors as economic issues, local conditions on site and the characteristics of the heating systems, while the decisions made dictate how the actual heat demand of the region will look like (see Figure 2). Notice that the demands presented in Figure 2 are symbolic and may not represent the actual future development. The appropriate solution is chosen on the basis of optimization of the various criteria, and some compromises have to be made.

Economy is one of the most important decision-making parameters when deciding on the heating method and energy self-production. The economic viability of the heating method is determined by heat energy tariffs, energy taxation, the price of technology, and possible incentives supporting particular technologies. The tariffs concern energy sale, purchase and transition determined by the local energy producers and distribution network operators. Taxation and incentive policies are the core methods in the realization of the regional sustainability policy.

Another important factor is the heating system -related personal preferences of the building operator. This encompasses personal requirements for comfort, namely ease of use, the quality of services, operational reliability, safety, etc. Also priorities in terms of social and environmental issues might play an important role. In this case, the realization of the regional sustainability policy can be boosted by rising social and environmental awareness of local residents.

Every property and building has its individual conditions and characteristics that affect the technical feasibility of each heating or energy production method. Some circumstances may limit out or favor the utilization of particular technologies. For instance, the characteristics of energy use vary significantly depending on the purpose of use of the building. One important energy use parameter is energy demand and its daily and annual variation. Site-specific climatic and geological conditions are detrimental for such systems as solar and geothermal heat production. Another important site-specific condition is the vicinity of a district heating (DH) network. It is rational to consider utilizing district heat whenever a DH network is available because of uncomplicated use, low need for maintenance, and competitive energy tariffs. The connection fee to DH is determined by the distance between the property and the DH network (Motiva, 2015).

Finally, the selection of the heating method is affected by the local regulatory framework that incorporates international and national laws and policies, as well as municipality-specific policies. In some cases the municipality can make the connection to the DH network obligatory by a local land use plan if a DH network is available, and if this will serve the local sustainability policy. In

Finland, the building operator can, however, derogate from this obligation if the building has low energy demand or the owner proposes a more efficient renewable heat source -based heating system (Ijäs, 2015). Some municipality-specific regulations related to geothermal heat extraction in groundwater areas and in the vicinity of water intake stations may apply (Town of Lahti 2015).

### **3.1.2 Centralized energy producer**

Centralized energy producers operate large-scale energy production plants producing heat and power for the needs of multiple customers (consumers/prosumers). Centralized energy producers are important contributors to the local sustainability targets of the municipality, as well as national and international targets. The coverage of centralized heat production can be on the level of a neighborhood, the whole municipality, or even neighboring municipalities. Centralized power production is connected to the national grid. The core interest of centralized energy producers is maintaining and increasing the profitability of their activities. Here, understanding the upcoming changes in the energy system is important in order to be able to adapt to the changes and utilize the emerging new business opportunities while managing the risks.

At the moment, centralized energy production is competitive. For example district heating (DH) accounts for 46% of the total heating market in Finland (Finnish Energy, 2015). However, competition is expected to grow. Self-production and ground thermal pump solutions are becoming the main competitors. Also the national and international regulatory framework and emission targets affect the competitiveness of centrally produced energy. Among these are emission trading, the Industrial Emissions directive with new nitrogen sulfur and particle emission limits, new national building codes promoting local renewable energy, and energy taxation. The new energy taxation measures which took effect in 2011 reduced the competitiveness of DH considerably, especially in the case of producers utilizing fossil fuels, like oil, coal and natural gas (Pöyry, 2011).

The future development of energy demand formation will affect the operation efficiency and profitability of the existing centralized energy production capacity greatly. Investments into energy producing technology are typically long. Investment decisions are made based on the market situation and the best available future market development prognosis at the moment of decision-making, see Figure 2. Technology sizing and fuel selections are optimized on the basis of the best available market knowledge at the time. The long duration of investments create a challenge for heat energy producers to adopt to new conditions in the case of unexpectedly high market fluctuation. For example a considerable drop in DH heat energy demand can lead to a decrease of production efficiency in some oversized production plants. This in turn can lead to decreased economy of production and a need for premature replacement investments of energy production technology. Decreased production efficiency also increases nominal GHG emissions of production, which is a drawback for the national and regional sustainability targets.

The main challenge for the centralized energy producer is identifying the optimal development scenario for the activities from the point of view of profitability of operations. The core scenarios to compare are whether the energy production capacity should be kept the same, increased or

reduced, which fuels should be used for production, what should be the price for energy, and how energy services should be tailored to suit the customers' needs best. Here understanding the mechanisms affecting the development of energy demand, as well as the influence of the regulatory framework, is required. Production capacity sizing decisions depend strongly on the energy demand. The main factor affecting the formation of energy demand is the consumer.

### **3.1.3 Energy distribution network operator**

Energy distribution network operators connect energy production with consumption. Basically, they operate two types of distribution networks, the district heating network and the electric power grid. The interests of the distribution network operator can vary, depending on the ownership of the network and other issues. The common interest of privately owned energy distribution network operators is profitability. However, if the operator is owned by the local municipality, the strategy is selected based on the municipality's sustainability targets. Here, in addition to maximization of municipal incomes, also a non-profit strategy can be applied with accent on the provision of necessary energy distribution services to local consumers. The profitability of energy distribution networks depends on the formation of energy demand and other preferences of energy consumers and prosumers in terms of the quality of the energy services. The transition efficiency of distribution networks depends on various transition losses and sub-system efficiencies. The introduction of energy storages can increase the overall transition efficiency. The efficiency of energy distribution can have a significant impact on primary energy consumption, and has thus major importance in terms of regional sustainability targets. The higher the heat losses during energy transition are, the more primary energy is required to cover the heat demand of the consumer (Vinokurov & Luoranen 2015). Traditionally, distribution networks have been designed to connect large centralized energy producers with residential, municipal or industrial consumers. However, the continuous increase in self-production requires some changes in the traditional design, because the energy produced by distributed solutions needs to be fed into network. Also the measuring of energy consumption and production should be improved, and appropriate tariffs for both the purchase and selling of energy should be introduced.

### **3.1.4 Municipality**

The municipality monitors and steers the development of the region in accordance with sustainability targets. The common interests of the municipality are ensuring the welfare of its residents, developing the economic attractiveness of the region, and providing the residents with services in an economically and environmentally sustainable way. On the regional level, decision-making related with the development of energy systems is highly affected by the national energy legislation and local energy policy. National-level regulation is for example carried out by target-oriented energy taxation. In Finland this means that for example the tax for fuel used in heat energy production is based on the energy content and GHG emissions of the fuel (Finnish Energy, 2011). The local energy policy is regulated by the municipality, and its framework is based on international and national energy-related targets, while paying attention to local municipality - specific sustainability targets related to the local climate, and social and economic, etc. conditions. There are different mechanisms the municipality can use to support the realization of the regional

energy plan. These are economic incentives that boost the introduction of a technology, such as renewable energy solutions, promoted by the energy plan. Another instrument is a land use planning system carried out by the municipality. The land use plan determines the future of the region by defining issues like what must be preserved, what can be built and where, and how the construction can take place. In some cases, the heating method to be used can be defined by the plan among other features, thus affecting the development of the local energy system (Ministry of the Environment of Finland, 2013). Here, a settled strategy of the regional energy plan plays an important role. For instance, if the municipality targets to decrease GHG emissions by investing in a costly centralized heating plant using biofuel, it might be rational to support DH system connections. Again, if because of different local conditions, biofuel is not easily available, it might be beneficiary to invest on different heating methods, for example on distributed production utilizing ground thermal heat pump technology. The revision of the local energy policy in the light of the changing conditions, and in some cases the change of policy might be beneficiary. Here comprehensive understanding of the current situation of the energy system and the effects brought by optional development scenarios is crucial.

### **3.1.5 New business opportunities**

Identifying the local actors, the relationships between them, and their interests, as well as the energy flows within the region will help to understand the current situation of the regional energy system in the light of the local sustainability policy, and thus the current development trend can be estimated. In addition, different optional development scenarios can be compared and it becomes possible to identify the optimal scenario that will support the realization of the local sustainability targets best. The approach presented here will also reveal the issues that are required to achieve the chosen targets, among these the challenges and new business possibilities for the different actors in the energy system.

One of the major future challenges for energy planning is the growing competition between DH and renewables-based self-production and geothermal heat pump technology. This situation will also create new business opportunities, however. For example, the continuously developing self-production systems and incentives promoting renewable local energy sources will increase the viability of energy self-production. Here the traditional consumer has the opportunity to become a producer of energy, selling energy to the distributor and receiving economic benefit.

The centralized energy producer can find an opportunity by providing a new energy service that includes the realization of centralized solar or geothermal heat production in the scale of a neighborhood, and providing energy to local consumers at an appropriate tariff. This can bring competitiveness for the centralized producer, as the consumer will receive locally produced renewable energy while being spared from laborious planning, construction and service, these being the responsibility of the centralized producer. This can be an actual development, especially when the competition with self-production is increasing.

For the energy distribution network operator, the main future challenge is to recognize upcoming changes in customers' demands and to adapt to them. In terms of increasing self-production, the

new business opportunity can be increasing the purchase of self-produced energy from prosumers and selling it to consumers who require energy at that moment. This would require changes in the network, but it could also create new incomes and ensure the demand for energy transition activities even if the demand for centrally produced energy were decreased.

New business possibilities can be provided also to other actors than those operating within the energy system. The analysis like one presented in this approach requires the collection and procession of a large amount of data and interpretation of the results, which is a task requiring certain professional expertise. This process should be controlled by the municipality, but depending on the available resources, these task can be fully or partially outsourced to specialized consulting agencies. This will create a demand for new consulting services. Also the business opportunities of technology producers will expand. For example, a major increase in renewables-based self-production will require new efficient heat storage technologies in the market.

## **4. Discussion**

The required emission reductions can be achieved by introducing local renewable energy sources and by increasing the efficiency of energy production, transition and utilization, and thus a regional approach is needed. These measures would require changes in the traditional energy system that has been designed to rely on large centralized energy production plants utilizing mainly fossil fuels. Increasing the decentralized production of energy by utilizing renewable energy sources provides a possibility to achieve local emission-free energy production. However, this will create new challenges for energy planning, since traditional energy systems have not been designed for decentralized energy production, and changes are required. Among the core challenges are the decreasing demand for centrally produced energy and issues related to feeding decentrally produced energy into the distribution network.

Achieving sustainability targets requires changes that will affect all the actors operating within the local energy system, creating new challenges, but also new sustainable business opportunities. Municipalities as overseeing authorities and responsible for steering the regional development have to acknowledge the present and upcoming challenges and opportunities and incorporate these into the decision-making process related to the development of the regional energy system. The approach presented in this paper is based on understanding the functionality of the local energy system by charting the different actors, energy flows and mechanisms in the system affecting the energy-related operations of the actors. The approach will help to understand the current state of the regional energy system in terms of sustainability, as well as to evaluate possible development scenarios. Following the presented framework will help to identify existing and upcoming challenges and new emerging business opportunities and incorporate the interests of different actors operating within the energy system into the decision-making. This can support local economic growth and increase the energy security of the region by increased local energy resource utilization while creating more local jobs. By understanding the mechanisms affecting the realization of sustainability targets, the decision-maker can choose the appropriate steering mechanisms to develop the energy system in accordance with the local policy.



The approach presented here is not intended to perform as a detailed energy analysis, but rather to provide guidelines for gaining a comprehensive overall picture on the current state and possible development scenarios of the energy system in terms of local sustainability targets. It is important to acknowledge that the presented approach is a common framework for systematic realization of regional energy analysis. Each region has specific conditions in terms of sustainability targets, actors, energy resource availability, climatic conditions, etc. These conditions should be taken into account when applying the framework. For example, the sustainability indicators should be selected according to region-specific sustainability targets. The approach may be accompanied with more advanced economic, environmental and social examinations, such as Life-Cycle Analysis, energy modeling, etc.

## **5. Conclusions**

Transition from traditional fossil fuel -based energy production towards the utilization of local renewable energy sources as well as an increase in the efficiency of energy production, distribution and utilization are important steps in achieving regional sustainability targets. These measures require changes in the traditional regional energy system, creating challenges as well as new opportunities for energy planning. If appropriately implemented, these changes can decrease the overall emissions while increasing energy security and economic wellbeing in the region.

This paper has presented an approach to identify and incorporate the interests, challenges and opportunities of different actors within the energy system systematically into the decision-making process related to regional development and energy planning. The approach is based on the identification of local conditions, such as actual actors with their interests, energy flows, local sustainability targets and case-specific sustainability indicators. This can give the decision-makers an overall view on the current state of the energy system, and help them to compare the effect of optional future development scenarios on the overall sustainability of the region. Therefore, the selection of the optimal development steering actions can be tailored to suit the region-specific conditions and needs.

## **6. Acknowledgements**

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# The Água Branca Urban Retrofit Project in São Paulo: Comparative Analysis to Paris Nord-Est Project

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## Abstract

With the constant growth of the world population, and limited resources on the planet, as well as the pursuit of better living conditions without consumption increase, it is necessary to create new methods of utilization of the urban structure ever built. Infrastructure constraints currently include ageing, underutilized and inadequate existing facilities, as well as a lack of integration in planning, design and management strategies for future infrastructure development in long-term scenarios. The urban retrofitting, one of the solutions to this problem, is usually defined as the occupation of degraded areas in town – such as misused, abandoned and/or empty ones –, making the transition from city actual situation to its future vision. This transition, or urban retrofit itself, shows comprehensive nature and large scale, integrated nature and a clearly defined set of goals and metrics for monitoring. Urban retrofitting presents great advantage over creating new urban developments and infrastructures, in point of view of urban sustainability. Therefore, this paper presents a comparative analysis of two case studies, urban retrofitting projects. The first one is the urban operation Água Branca, in the city of São Paulo, an area with substantial transformations in the urban municipality, since 1995, in order to provide a more densely populated neighbourhood, with mixed use, inclusion and social diversity. The second project is the Opération Paris Nord-Est, northern suburbs of Paris, started in 2002 with the purpose of transforming this outlying area in a new economic and urban centre, through retrofitting existing infrastructure and promoting mixed-use, commercial and residential. The research method included a literature and documents review, consultations, interviews and technical visits. The result is a comparison of two retrofit projects, in São Paulo and Paris urban contexts, in terms of similarities and differences between priorities, perspectives, guidelines and urban policies, using urban indicators to quantify comparisons, such as: area for construction, population density, floor area ratio and green space areas, and listing respective advantages and disadvantages of urban retrofitting implementation process.

**Keywords:** Urban Sustainability, Urban Retrofitting, Urban Renovation, Urban Redevelopment

# 1 Introduction

The United Nations Human Settlements Programme (UN-Habitat, 2009) identified eight major trends in the integration of the green agendas in cities, that focus on: “developing renewable energy; striving for carbon-neutral cities; developing distributed power and water systems; increasing photosynthetic spaces as part of green infrastructure; improving eco-efficiency; increasing sense of place; developing sustainable transport; and developing cities without slums”. More recently, Newton (2013) highlights a number of critical issues for cities, that are likely to intensify by mid-century unless concerted interventions commence, which are: “climate change, resource constraints, population change, urbanization and intensification of urban development, ageing infrastructure, socio-demographic change, urban economic base and financial uncertainty”.

In order to reach those objectives, many projects have been proposed, such as retrofitting ones, that uses older buildings and develops a range of ecological and/or technical adaptations. The concept of urban retrofitting or re-engineering has gained ground globally in recent years, with a sustainable approach. Sustainable urban retrofitting regards the “directed alteration of the fabric, forms or systems which comprise the built environment in order to improve energy, water and waste efficiencies” (Dixon and Eames, 2013). However, for cities, larger-scale and more integrated and sustainable systems or enterprises are needed. According to Living Cities (2010), the defining characteristics of a larger-scale retrofit system are these: comprehensive scale, integrated, sufficient and sustainable funding, deliberate and systematic strategy for engaging and benefitting lower-income people, and robust performance management system with a set of clearly defined goals and metrics for monitoring.

Newton (2013) says that “urban regeneration, renewal, redevelopment, rebuilding, renovation, restoration and retrofit are all terms that have been used somewhat interchangeably in the literature to describe the processes aimed at revitalizing the existing built environment, local communities and local economies”. They encapsulate the multiple dimensions represented in urban redevelopment, including scope, ownership and governance.

Therefore, the urban retrofitting is usually defined as the occupation of degraded areas in town – such as misused, abandoned and/or empty ones –, making the transition from city actual situation to its future vision, in long term scenarios. This transition, or urban retrofit itself, shows comprehensive nature and large scale, integrated nature and a clearly defined set of goals and metrics for monitoring. Urban retrofitting projects are a set of interventions in order to adapt the urban area to improve its sustainability, not only at present time, facing current demands and problems, but also for future population and needs. Usually these projects cover former urban areas, around public transportation stations, or industrial areas, i.e. environmentally fragile lands, empty or not. Retrofitting adaptations involve a whole range of issues related to urban sustainability, such as: housing, energy, water, waste, walkability, existing buildings.

Urban retrofitting presents great advantage over creating new urban developments and infrastructures, in point of view of urban sustainability. Expanding cities towards occupying

natural lands and greenfields, improving environmental and ecological impacts on building new urban infrastructure, seems to be a less sustainable alternative facing developing urban areas with wide configurations and uses, in order to occupy decayed areas and brownfields.

In fact, in a period of economic crisis, rather than thinking of large incremental development plans, it is wiser to suggest urban retrofitting operations conceived as the punctual nodes of a longer term re-planning, as they have the potential to generate new identity processes at the urban scale (Ferrante and Semprini, 2011). Dismantling and re-building cities is not a realistic option and abandoning urban areas is not a preferable alternative.

Furthermore, the retrofit of a neighbourhood must be coherent with the city as a whole. It needs to tackle the local issues of the area as well as the more global challenges of the city, such as car congestion, pollution or flooding risks. This is why urban retrofit operations are often encapsulated in each other, creating a strategic director plan for the city future.

## 2 Methodology

The aim of this paper is to study urban retrofit processes, so this research presents a comparative analysis of two case studies, urban retrofitting projects, a comparative case, here preferable to a single in-depth case because the analysis also assess how these two retrofit projects address the challenges of each respective background, the city where each one belongs to.

The first urban retrofitting project is the urban operation *Água Branca*, in the city of São Paulo, an area with substantial transformations in the urban municipality, since 1995, in order to provide a more densely populated neighbourhood, with mixed use, inclusion and social diversity. The analysis determined how the retrofitting project could improve the living conditions in the area, by bringing balance and dynamism to this uneven and unequal yet pivotal neighbourhood, and meet the challenges of São Paulo, a giant and ever growing metropolis in a developing country, Brazil.

The second project is the *Opération Paris Nord-Est*, northern suburbs of Paris, started in 2002 with the purpose of transforming this outlying area in a new economic and urban centre, through retrofitting existing infrastructure and promoting mixed-use, commercial and residential. The research determined how this project, located in Paris, a more ancient and more slowly growing metropolis of a developed country, is different from the previous one, both in the urban issues at stake and the proposed solutions.

Many urban projects are under development in São Paulo municipality, but the urban operations demonstrate affinity to urban retrofitting concept, since they present neighbourhood and district scale, long term implementation and agreement to strategic plans and future city scenarios. According to the Ministry of Cities (Ministério das Cidades, 2008), the urban operation concept was influenced, to a certain extent, by international experiences, such *Zones D'Aménagement Concerté – ZAC*, or joint development zones, that appeared in France in 1970s. French ZACs assumed more state interference, by means of direct actions for urbanization, mobilization and

recovering the value of local real estate for community, submitting private capital to public interests and priorities. However, in Brazil, urban operations appeared in other line, more linked to negotiation of urban laws exceptions by the State, in order to get resources to urban development actions.

The research method included a literature and documents review, consultations, interviews and technical visits. The current situation of both neighbourhoods was analyzed as a whole, by highlighting their population, economic data and drainage issues. The both urban retrofitting plans show present and future situations, under main guidelines and urban policies involved in the process. Some urban indicators and parameters were selected to assess comparisons.

The objectives of urban retrofit can be quite different from a country to another. Western countries must cope with ageing building stock and urban infrastructures and cities while developing countries need to retrofit informal and unplanned urban developments to tackle the issues of poverty, housing, economic growth, energy insecurities and climate change. We will compare Água Branca with a French retrofitting project to see if the objectives of urban retrofit are always very different.

## **2.1 The urban operation Água Branca**

In 2010, the *Prefeitura do Município de São Paulo*, or São Paulo Municipality, presented a report entitled “SP 2040: the city we want” (PMSP, 2012), that diagnoses current situation and foresees scenarios for 2040. São Paulo is the biggest city in South America, with over 11 million of inhabitants and 20 million in the metropolitan area, and it is still growing at a rapid pace, with an increase of 1,65 per cent per year for the period 1991-2010 in the metropolitan area (PMSP, 2012). The city is coping with multiple challenges, which make urban planning increasingly difficult for the city council. How urban planners will tackle these challenges will prove very useful to improve living conditions for the 85 per cent of Brazilians who live in the cities.

As in Brazil as a whole, economic inequality is significant in São Paulo: 15 per cent of the population live in favelas, shanty towns mainly located in the outskirts of the city (PMSP, 2012). Meanwhile, the richest inhabitants live in the city centre, often in “condominiums”, luxurious and highly-guarded residences. PMSP (2012) presents a trend scenario for 2040, with a projection of current problems. City population is estimated to around 12,1 million inhabitants in 2040, while metropolitan population will reach 22,5 million inhabitants.

The joint urban operation Água Branca, or *Operação Urbana Consorciada – OUC Água Branca*, was select for study because is a project under development, initiated in 1995. With easy access, Água Branca is located in the Municipality of São Paulo, within the main beltway. It extends over 540 hectares along the south side of the Tietê River (PMSP, 2014). The Água Branca area was designated for a retrofit operation because it was located in the city center and the displacement of industries left it unbalanced. The significant amount of public transportation, namely train and metro, was also a reason of the retrofit of the area. In 2010, the population of the Água Branca area is 29.815 inhabitants, and the population density is 55 inhabitants per hectare, which means

that it is not densely populated (EMURB, 2009) comparing to population density in São Paulo metropolitan area, that is 75 inhabitants per hectare. The objective is to significantly increase this number, with an objective of 86.289 inhabitants, i.e. a sharp increase of 189% in the population (EMURB, 2009). Sectors with former industrial lands with no inhabitants will be largely transformed, by creation of many streets and major housing projects.

The following figures represent an aerial view of the Água Branca neighbourhood and the urban plan of the retrofit, and the following table is a synthesis of the changes brought to Água Branca by the retrofit.



Figure 1: Aerial view of the Água Branca neighborhood (PMSP, 2014)



Figure 2: Urban plan - Água Branca neighborhood (PMSP, 2014)

Table 1: Numerical synthesis of the changes brought by the Água Branca operation

Data	Água Branca in 2014	Future Água Branca (after project implementation)
Total Area	540 ha	540 ha
Population Density	61 inhab/ha	177 inhab/ha
Empty Areas	50 ha	0
Residential Area Stock	30 ha 5100 unities	0
Non-Residential Area Stock	51,2 ha	0
Green Space Areas	10 ha	42 ha
Green Space Areas (% of total area)	7%	19%
Road System Area (% of total area)	16%	25%

Adapted from EMURB (2009), PMSP (2014) and WALM (2009)

## 2.2 The Paris Nord-Est Project

According to *Préfecture de Paris* (2010), or Paris Municipality, *Gran Projet Renouvellement Urbain – G.P.R.U.*, or Big Urban Renewal Project, initiated on March 2001, in order to improve structure and quality of life in eleven priority neighbourhoods, remotes from city center, covering 200.000 residents and seven districts, through participative actions, public consultations and long term projects, including the urban revitalization and renewal of a big area in North-East region of Paris.



One of the eleven neighbourhoods, the Paris Nord-Est project was initiated in 2002 by the city council, following the significant retrofit of the nearby neighbourhood of the *Plaine Saint-Denis*, in the northern suburbs of Paris, which has recently become a very dynamic economic area. The area of the project covers 220 hectares, alongside the *Boulevard Périphérique*, which represents the limit between Paris and its northern suburbs (*Préfecture de Paris*, 2014).

The aim of the project is to transform an outlying area into a new economic and urban center by retrofitting decaying infrastructures and by benefiting more efficiently from existing infrastructures such as the *Boulevard Périphérique* or the A1 Motorway. Paris Nord-Est will become a more mixed area, with offices, facilities and housing. All the parts of the retrofit are expected to be completed by 2020.

Paris Nord-Est area is characterized by the considerable presence of networks, with the railways from both *Gare du Nord* and *Gare de l'Est*, the A1 motorway, the *Peripheral Boulevard* – which may be regarded as the physical limit of the city of Paris –, the *Boulevard des Maréchaux* – a boulevard that also encircles the city center), and the Saint-Denis canal. Despite its large area, the area is seen as undervalued and landlocked. Currently, Paris Nord-Est has only 13 000 inhabitants and 16 000 jobs (*Préfecture de Paris*, 2014).

The objective of the urban retrofit is to revitalize this pivotal neighbourhood by creating 25 000 new jobs and by allowing the settlement of 10 000 new inhabitants (*Préfecture de Paris*, 2014). The priorities of the retrofit are:

- to improve quality of life throughout the area by requalifying public spaces and the main infrastructures (boulevards, public squares, “*portes*” of Paris, canals)
- to open up the neighbourhood by benefiting more from the proximity of important networks
- to create new economic cores within the Paris metropolis with activities, shops, rail freight and urban services that will create jobs for the inhabitants of this disadvantaged neighbourhood

According to *Préfecture de Paris* (2007), new built area will cover 1.1 million of square meters (110 ha). During this retrofit, approximately 233 000 square meters (21% of the built area) will be destroyed to make space for new buildings. There will also be around 27 hectares of green spaces once the retrofit is over. The current situation and the proposed plan are shown at following figures, and the following table is a synthesis of the changes brought to Paris Nord-Est by the retrofit.



Figure 3: Aerial view of the Paris Nord-Est area (*Préfecture de Paris*, 2014)



Figure 4: Paris Nord-Est – Urban Plan (*Préfecture de Paris*, 2014)

Table 2: Numerical synthesis of the changes brought by the Paris Nord-Est Project

<i>Data</i>	<i>Paris Nord-Est in 2013</i>	<i>Future Paris Nord-Est (after project implementation)</i>
<i>Total Area</i>	220 ha	220 ha
<i>Population Density</i>	59 inhab/ha	105 inhab/ha
<i>Empty Areas</i>	23,3 ha	0
<i>Residential Area Stock</i>	44 ha (50% to social housing)	0
<i>Non-Residential Area Stock</i>	66 ha	0
<i>Green Space Areas</i>	11 ha	27 ha
<i>Green Space Areas (% of total area)</i>	5%	12%

Adapted from Préfecture de Paris (2007) and Préfecture de Paris (2014)

Paris Nord-Est is already a socially-mixed area, with a large share of low-income households. The project takes this into account with a minimum objective of 50% of social housing on the new housing projects (Préfecture de Paris, 2007).

The retrofit aims also at increasing the population density in the various sectors of the project. On the former railways, there are only few inhabitants: the increase in population density will be thus very important. However, in the south of Paris Nord-Est, the urban fabric is already densely built and populated. Nevertheless, studies are being made to assess with precision where improvements in construction and population density are still possible.

### 3 Results

From the comparative analysis between Água Branca and Paris Nord-Est projects, urban indicators were identified and, however, provide results with common points and differences between both projects. These indicators and parameters are presented and discussed below.

#### 3.1 Land use characteristics

The following table compares some current urban parameters of land use, showing occupancy and dimensions, both in São Paulo city and Paris. Main areas of São Paulo were selected due they better represent Água Branca project areas.

Table 3: Urban parameters of some areas in São Paulo and Paris

<i>City</i>	<i>Area</i>	<i>Floor Area Ratio</i>			<i>Maximum Building Height (m)</i>	<i>Minimum Front Setback (m)</i>
		<i>Minimum</i>	<i>Basic</i>	<i>Maximum</i>		
São Paulo	High Density Area	0,05	2,00	2,50	no limits	5
	Polar Centre Area	0,20	2,00	4,00	no limits	5
Paris	Centre	none	1,50	3,00	between 35 and 42	between 6 and 8

Adapted from IAURIF (2005) and PMSP (2004)

### 3.2 Area for construction

Table 4 shows differences between destination of new areas for construction of each one of the comparative projects. Both projects have comparable total area for new constructions, but the destination of Paris Nord-Est project is more balanced than Água Branca. Area destined for new housing is also larger in Paris.

*Table 4: Destination of new areas for construction of Água Branca and Paris Nord-Est Projects*

Destination of new areas for construction	Água Branca		Paris Nord-Est	
	ha	% of total	ha	% of total
Housing	30	25	44	40
Equipments	24	20	11	10
Business Activities	24	20	55	50
Others	90	35		
<b>Total</b>	<b>120</b>	<b>100</b>	<b>110</b>	<b>100</b>

*Adapted from PMSP (2014) and Préfecture de Paris (2013)*

### 3.3 Population Density

The following table shows the evolution of population densities in Água Branca and in Paris Nord-Est projects, as well as in São Paulo city and in Paris. Paris, with current 201,6 inhabitants per hectare is a much more densely populated city than São Paulo, with 73,8 inhabitants per hectare. This will not change much over time.

*Table 5: Population densities evolution in Água Branca and Paris Nord-Est Projects, and in São Paulo and Paris*

Population Density (inhab/ha)	Água Branca	São Paulo	Paris Nord-Est	Paris
Current	61,0	73,8	59,1	201,6
Future	177,0	78,3	104,5	209,8
Increase	190%	6%	76%	4%

*Adapted from WALM (2009) and Préfecture de Paris (2007)*

Água Branca will see its population density almost triple, overcoming the population density in Paris Nord-Est, despite that the last will increase by 76%. This difference in population density of both projects can be explained by the different potential of each neighbourhood. In Água Branca, the majority of the area is occupied by former industrial lots, which can easily be retrofitted. In Paris Nord-Est, however, railways occupy a significant amount of space, which limit the population increase over the whole neighbourhood.

### 3.4 Floor Area Ratio

In both neighbourhoods, the floor area ratio will increase where an increase in population density is projected. The buildings will be higher and denser to house more people and jobs. The two neighbourhoods possess empty land, where the increase in floor area ratio will be the most significant.

In Água Branca, some social housing projects with a floor area ratio over 3 will be built in areas where the floor area ratio used to be 1,00. Along the up-righting axes, the increase in floor area ratio will also be significant, thanks also to the maximum housing quota scheme and to the curbing of parking places.

In Paris Nord-Est, the increase in floor area ratio will be easy along the former railways and on the former industrial lands. Yet, in the south of Paris Nord-Est, it will be more difficult to find spaces for a potential increase in floor area ratio, since the area is already densely built. Additional constructions will be decided on a case by case basis. Below is an example of a detected potential for a new construction, although the floor area ratio of the lot is already 2,38 (*Préfecture de Paris*, 2013).

### 3.5 Green Space Areas

The following table shows the green spaces in the current and future neighbourhoods. There will be a significant increase in the total green spaces in both neighbourhoods, in the end of urban retrofitting projects.

Table 6: Green spaces evolution in Água Branca and Paris Nord-Est Projects

Green Spaces	Água Branca		Paris Nord-Est	
	ha	% of total	ha	% do total
Current	10	2	11	5
Future	42	8	27	12
Increase	6%		7%	

Adapted from PMSP (2014) and Préfecture de Paris (2013)

Água Branca will see its total green spaces quadruple due to the retrofit, creating projected new parks. In Paris Nord-Est, green spaces will represent 12 % of the area once the retrofit is over, which is quite significant. In Paris, the percentage of green spaces is 17%, which includes two forests: Bois de Vincennes and Bois de Boulogne (*Préfecture de Paris*, 2013).

## 4 Discussion

The issues tackled by both retrofit operations are the same as Água Branca and Paris Nord-Est are two quite similar neighbourhoods: they both include large former industrial lots, with obsolete infrastructures. Despite their strategic location within the city, they are both undervalued and landlocked. They also have a low density of population.

As Água Branca, Paris Nord-Est is an undervalued neighbourhood because it is landlocked and there are many dilapidated infrastructures. Moreover, the neighbourhood is dislocated due to the railways and the *Boulevard Périphérique*. In order to open up the neighbourhood, 6 transversal paths will be renewed or created (*Préfecture de Paris*, 2007). These paths through the neighbourhood will bring dynamism and visual references to the neighbourhood, like the up-righting axes of Água Branca (PMSP, 2014), connecting it to the surrounding areas.

The local issues of both neighbourhood explain why these two urban retrofit projects, located in two very different cities, have many similarities. The objective to create a more densely populated neighbourhood is the same, as is the goal to induce a socially-mixed neighbourhood with social housing and incentives for low-income households. There is also a common focus on green spaces: both neighbourhoods will see a significant increase in the total areas of green space and in the number of trees along the main streets. Moreover, the two projects tend to enhance the landscape in the same way with several linear parks to create new visual references within the neighbourhood. The main objective of both projects is to create a more compact and liveable city.

Increasing the areas of green spaces is regarded as a way of enhancing the landscape of the neighbourhood and to improve the living conditions in the area. Moreover, green spaces restore the physical cohesion of the neighbourhood. In Paris Nord-Est project, at the end of the retrofit, there will be 27 hectares of green spaces. There will also be a linear park along the second pathway, between *Charles Hermite* and *Plaine Commune* (*Préfecture de Paris*, 2014). It will have the same function as the linear parks in Água Branca, enhancing the landscape for pedestrians and bicycles alike (PMSP, 2014). In Paris Nord-Est project, the comparison between former and future green space distribution highlights how the city of Paris manages to retrofit sectors that used to be dedicated to the main urban services such as railways. The conservation of the empty spaces created by the railways and their transformation into parks is a unique opportunity for the city, as it allows all the public spaces in the sector to spread from there. The *Jardin d'Eole* becomes one of the largest green area in the whole 18<sup>th</sup> *arrondissement* (district).

The comparative analysis shows that both projects want to fulfil the demands of their citizens by making their life better and more comfortable, improving the landscape, and reducing economic inequalities. It indicates how necessary it is to understand the habits and the behaviour of the citizens, and how important the projects have to cope with politics and institutions.

Differences appear in the way retrofits need to change the cities. In Paris, the large-scale objective is to revive a developed metropolis which may lack dynamism by focusing on its neglected and landlocked territories while, in São Paulo, the main challenge is to guide an uncontrolled urban dynamism and sprawl, by bringing more coherence and more density to the city and more balance to social inequalities. This may explain why the Paris Nord-Est project is more focused on job creation to boost the neighbourhood whereas the Água Branca operation is more centered on providing a larger housing offer to the city.

Moreover, some of the priorities of each project are different. For instance, Água Branca needs improvements to its drainage system due to flooding risks, which are much lower in Paris. Furthermore, as congestion issues are much greater and cars were always given the priority in São Paulo, the urban retrofit project of Água Branca tackles car traffic by curbing parking places with a new dedicated policy and by encouraging bicycle use and pedestrian circulation. In the meantime, the curbing of car use is already well in place in Paris, where many city dwellers often don't need to own a car because of an efficient, extensive public transport network.

Besides the analysis of urban indicators and parameters, it is important to know the context about urbanism and historic, political and cultural issues of both cities. São Paulo and Paris, are utterly different. The notion of adaptability is necessary and it must be understood that every solution of urban retrofitting needs to be considered from a more global point of view before being implemented. Moreover, Água Branca Operation and Paris Nord-Est show that societal and political support are inevitable requirements. As transitions like urban retrofitting processes have characteristics as sufficient and sustainable funding, and deliberate and systematic strategy for engaging and benefitting lower-income people (Living Cities, 2010), this is important to consider the political dynamics of their host cities and regions. And the temporal dimension of urban retrofitting transitions requires further policy attention.

These two retrofit projects analysed in this paper, the joint urban operation Água Branca and Paris Nord-Est, both adapt their priorities to their city's current main issues. Nevertheless, they have surprisingly close objectives regarding social inclusion in the neighbourhood, green area expansion and increased construction density.

## 5 Conclusion

The urban operation Água Branca is an ambitious urban retrofit project that aims at creating a whole new neighbourhood, which will be more compact and liveable. This retrofit must not only tackle the inherent problems of the neighbourhood, such as flooding risks, but also São Paulo's main urban issues, such as social and economic inequalities and congestion. It does so by resorting to classical urban ideas as well as resorting to new urban policies. It copes with São Paulo's significant economic inequalities by creating a more socially-mixed neighbourhood not only through incentives for social housing but also through a maximum quota per housing unit scheme that allows more low and middle-income households to come to live in the neighbourhood. Besides, thanks to a new policy that curbs parking places, it tackles São Paulo's notorious car traffic by increasing the area of green spaces and by expanding sideways to give the city back to its inhabitants.

Urban parameters help to assess the change brought to the neighbourhood by the retrofit. The division of lots, the extension of green spaces and of streets should also help to create a more liveable area. Land use and ratios are crucial to determine how the area is transforming thanks to the retrofit. Thus, the densification of the area needs to be regarded as an obstacle in the urban sprawl of São Paulo.

The comparison analysis with the Paris Nord-Est project shows that urban retrofit projects tend to have surprisingly similar objectives throughout the world, even though they must be adapted to the issues of the area. It also highlights the fact that the retrofits of neighbourhood always take into account the larger urban picture and the issues of the city in which these neighbourhoods are located. Moreover, drawing comparisons between these two retrofits, located respectively in a developed country and in a developing one, may give new interesting ideas to both urban retrofitting projects.

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# Global Sustainable Perspectives X3: North America, Europe, and Africa

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## Abstract

Sustainable practices differ considerably within nations and are significantly more dramatically apparent when a contrast is made amongst nations from three major continents. As well, if one does not look carefully at the criteria for sustainable terms, one can be easily misled in the meaning of sustainability. The paper will show how a collaborative effort with three educators in three institutions working within their standard rating systems reveals the challenges of sustainability indicators – carbon footprint / ecological footprint. The indicators for each educator are presented and analysed as one bases of comparison. The ethics of the differences were explored through the value systems that are embedded in each of the rating system. The ethical perspective the authors hypothesize brings about a needed and robust political discussion first with intentions for cooperation and collaborations in the future for a sustainable built environment that is equitable and achievable at the most significant level. The sustainable rating systems were analysed and compared for effectiveness with a rubric that will suggest plans for adaptation to other regions, both locally and globally. Common ground, or clarity, in the rating systems were illustrated with suggestions for productive collaborations that could benefit the larger ethical dimensions within the future of the built environment.

**Keywords:** Built Environment, Carbon footprint (CFP), Ecological footprint (EFP), Sustainability

# 1. Introduction

When the three authors of this paper undertook to research the differences in individual carbon footprints (CFP) of three different countries; a key assumption (#1) was that there would be major differences in each country's respective average CFP. Naturally, as perceptions and assumptions go, it was expected that the Netherlands would have the lowest CFP, followed by South Africa and then the United States of America (USA). However, this was not the case, because infrastructure and or state sponsored programs are factored into individual footprints. More interesting was the fact that there was not a greater difference than was expected. Understanding the criteria used to create a carbon foot print assessment reveals important nuances that will help understand how one can make a difference. The carbon emission data from the World Bank development indicators in terms of metric tons per capital show that South Africa has the least emissions at 9.3 whereas the USA has the highest among the three countries at 17 and emission data for the Netherlands follows that of South Africa at 10.1 (World Bank, 2015).

The motivation and the overarching question that the authors wanted to address in doing this comparative study is "how do you change the individual CFP of a nation" if it were known that there are others who have a greater CFP and they are not willing or able to lower their footprint. As well the authors believe governments can more easily impact the built environment, construction, and buildings, because the many stakeholders involved in the construction process are often tied to government policies. That is, lending agencies, regulatory agencies, legislation for public project are frequently incentivized quite often require public monies and thereby more easily made to follow the "enlightened public self-interest" standards. Construction amounts to 40% of all energy needs consumed in the USA (Kibert, 2013) of which many projects are funded through public agencies imposing standards that are more global. Focusing on the individual footprint would have greater variability, although an office building is an office building whether in Netherlands, USA or South Africa.

The next major assumption (#2) was that this motivating factor was related to knowledge, awareness and willingness to do so. But the study shows that these factors were not the main factors that are necessarily changing CFP. The next section is a concise description of the research process. This is followed by the findings on CFP and ecological footprints (EFP) of the educators. In the discussion section, the nuances of the findings are conceptualised in terms of sustainability in the built environment and the complexities that are associated with the ideas related to sustainability and changing behaviours.

## 2. Synopsis of the Desktop Study

The paper is based on a study of secondary sources / information for their contents and explanations (Krippendorff, 2013). The study began with a visit to the website of the World Bank Group as indicated in this section of the paper. The authors looked at the data concerning CO<sub>2</sub> emissions (metric tons per capita) Indicator Metadata. Using the World Bank definition on the website - "Carbon dioxide emissions are those stemming from the burning of fossil fuels

and the manufacture of cement. They include carbon dioxide produced during consumption of solid, liquid, and gas fuels and gas flaring”; this study view CFP as the greenhouse gas (GHG) emission to the environment by a person or an organization.

Based on the World Bank data of the Netherlands, South Africa, and USA mentioned earlier and the illustration of Figure 1, the authors were able to learn that the differences between these nations that are located in three separate continents were not as dramatic. For instance, the USA is not only on the top of the scale globally, and even the nations are not so far apart when you consider the lowest and highest CO<sub>2</sub> footprint nations (World Bank, 2015).



*Figure 1: SA, NL, USA and two most extreme nations*

The information on the development indicators of the World Bank (2015) is insightful as shown in Table 1. The indices on the World Bank (2015) website show the rating for 195 nations. The data indicate that 60 nations have less than 1.0 index, 110 nations have  $1.0 \geq 10.0 \leq$ , 21 nations have  $10.0 \geq 20.0 \leq$ , and only 8 nations have  $20.0 \geq 44.0 \leq$ . It is notable that people or population is not indicative of the extent of carbon emissions from a country. Table 1 shows that the top nations have fewer populations whereas the low emitters have large people living within their borders. At best, it can be argued that the lifestyle of the overall people may have marginal influences on carbon emission, while the main factor may be the type of industries servicing an economy. This is evident as the top emitters run economies that depend on fossil fuel while the least emitters are basically less industrialised countries in Africa.

To put this argument in perspective, although the indices for both South Africa and the Netherlands are close (9.3 and 10.1 respectively); there is a wide gap in the number of people living in both countries. According to the fact book of the Central Intelligence Agency (CIA) of the USA, the population of South Africa is 53,675,563 and that of the Netherlands is 16,947,904 as at July 2015. These figures are even far behind the population of the USA, which stood at 321,368,864. In fact, the populated nations of China and India have 6.7 and 1.7 indices

respectively. These illustrations support the argument that the main driver of growth and environmental degradation is not population per se, but consumption patterns and levels multiplied by the number of consumers, especially in developed economies (Toth and Szigeti, 2015). These disparities between the carbon emission indices and population imply that individual behaviours are yet to significantly impact the amount of emissions from a country. In other words, the calculation of CFP should go beyond individual behaviour and focus on a more comprehensive form of information that may be captured in an EFP calculator.

Table 1: A summarised CO<sub>2</sub> 2011-2015 emission indicators (metric tons per capital)

Top 10			Bottom 10		
Country	Index	People	Country	Index	People
Qatar	44.0	2,194,817	Burundi	0.0	10,742,276
Trinidad and Tobago	37.1	1,222,363	Chad	0.0	11,631,456
Kuwait	28.1	2,788,534	Burkina Faso	0.1	18,931,686
Brunei Darussalam	24.4	429,646	Eritrea	0.1	6,527,689
Aruba	23.9	112,162	Ethiopia	0.1	99,465,819
Luxembourg	20.9	570,252	Malawi	0.1	17,964,697
United Arab Emirates	20.4	5,779,760	Mali	0.1	16,955,536
Oman	20.2	3,286,936	Rwanda	0.1	12,661,733
Saudi Arabia	18.1	27,752,316	Niger	0.1	18,045,729
Bahrain	17.9	1,346,613	Guinea-Bissau	0.1	1,726,170

*Sources: World Bank (2015); CIA Fact book (2015)*

To give strength to the initial purpose of the research, the authors submitted personal information into CFP calculators. The authors selected the calculators based on a Google search for the top-three visited CFP calculators in each country to select the most used calculator. However, the search results for individual author differs and more worrisome is that a common top calculator is only available to residents of USA alone. Thus, a common calculator for CFP for the three authors was not identified. The story is not the same with the EFP calculator, which allow the authors to take similar test that allows consistent comparison between their countries. The decision to take a test based on EFP is also born out of the fact that CFP is a component of EFP. Although EFP and the CFP are matrices for measuring the impact of routine human activity on the environment, both matrices differ in their scope, expression of impact values, and the perspectives of calculations. For example, the CFP takes into account only the activities related to GHG (Weidema et al., 2008), which are directly influenced by fossil fuel burning, and indirectly by electricity consumption.

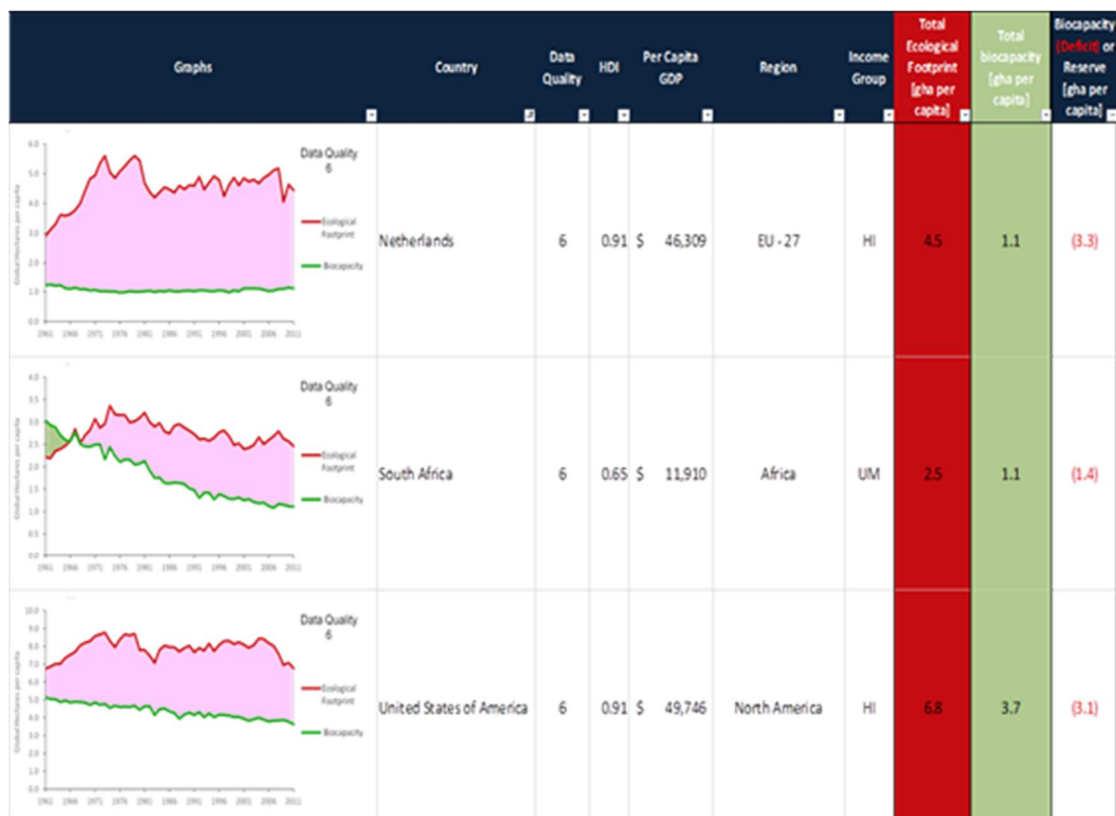


Figure 2: Snapshot of national ecological footprint of three countries (source: GFN, 2015)

The CFP thus gives the raw amount of carbon emission in tonnes per year as an output. In contrast, the EFP describes the entire activities a person is involved in, and the resources utilized as well as the wastage generated through such activities. It measures how much of the biosphere's annual regenerative capacity is required to renew the natural resources used by a defined population in a given year (Venetoulis and Talberth, 2008). The EFP gives values of the land and water area that is needed to replace the resources consumed – these directly affect the built environment in terms of construction and use of materials in the industry. In brief, the CFP metric aims to reduce the impact on the environment by reducing global warming and evading catastrophes while the EFP takes all problems of the environment as a whole and target sustainable development as a goal.

### 3. Ecological footprint exploration – national metrics

This distinction between the CFP and the EFP and the need to use a consistent tool by the authors lead to the use of the calculator of the Global Footprint Network (GFN). The calculator, [www.footprintnetwork.org/en/index.php/GFN/page/personal\\_footprint/](http://www.footprintnetwork.org/en/index.php/GFN/page/personal_footprint/), was used to compute the individual footprint of the authors and their home countries. The terminologies of GFN (2015) calculator include biocapacity, which serves as a lens that shows the capacity of biosphere to regenerate and provide for life; and the global hectare (gha), which is a biologically production hectare with world average productivity.

When the behaviour of those deemed sustainable friendly and environmentally most conservative, yet maintain levels of consumption in excess of the global standards by a factor

as much as two (ScienceDaily, 2008) one has to be concerned with motivation. Factors such as military, infrastructure and roads, public expenditures etc., that increase the average CFP may attribute to the attitude.

#### 4. Ecological footprint exploration– personal metrics

When the authors calculated their individual EFP, the data shown in Table 2 and Table 3 were produced through the GFN calculator. In Table 2, impact refers to the activities that impact personal footprint. For instance, if everyone lived like Anton, humanity would need 3.0 planet earths to provide enough resources, and to support the lifestyle of Anton, it takes 6.3 global acres of the earth's productive area that include all the six EFP components. Among these components, CFP of Anton has been estimated to be 18.4 tons.

In addition, Table 3 shows the breakdown of the personal EFP of the authors. In ranking order, services, shelter, food, goods, and mobility constitute the percentage contributions of activities, which make up the EFP of Anton.

For the author resident in South Africa with a family of four and an SUV for mobility, impact is rated at 2.4 and to keep the lifestyle going, 4.4 global acres of the earth's productive area shall be required. It is however notable that the test undertaken in South Africa did not produce the CO<sub>2</sub> emission estimate for Fidelis. Although the authors answered very similar questions on the GFN calculator, the calculation of the metrics may be country dependent, hence the lack of CO<sub>2</sub> data for the South African author. As illustrated in Table 3, food and shelter contribute the most to the personal footprint of Fidelis. In other words, if Fidelis is to reduce his EFP, these are the parts that he should influence.

*Table 2: Comparative personal ecological footprints of authors*

Author	Country	Impact	Support	CO <sub>2</sub> (tons)
Anton	Holland	3.0	6.3	18.4
Fidelis	South Africa	2.4	4.4	-
Erich	USA	4.4	19.8	22.0

*Source: Authors*

The American author also undertook the same test on the GFN portal to produce the data displayed in Table 2 and Table 3. The data is self-reported into the calculator and depending on the circumstances of how one view their circumstances can make a significant difference in the score. For example, the American author lives in a different location from his family due to his employment. His household compared to the Dutch author with same number of children, which consists a total of five residences and five cars and whereas the Dutch author has one residence and two vehicles, but the criteria based on the calculator inputs did not account for these differences, which then would make dramatic changes in the comparative scores. The Dutch motivation may be associated with the fact that the government taxes Co<sub>2</sub> unfriendly and subsidize Co<sub>2</sub> friendly practices in manufacturing, travel, design and construction. These are successful in changing consumer's behavior. Owning / using a car in the Netherlands is approximately three times more expensive

as in the USA, and the public transportation system is partially financed by private vehicle taxes and the same logic is applied to Co<sub>2</sub> emissions of buildings.

*Table 3: Comparative personal ecological footprints of authors – break down in ranking format*

Criterion	Anton	Fidelis	Erich
Food	3	1	3
Shelter	2	2	4
Mobility	5	3	5
Goods	4	4	2
Services	1	5	1

*Source: Authors*

## 5. Discussion

In “*Footprints to nowhere*” (Giampietro and Saltelli, 2014) cast doubts on the ability of EFP and CFP metrics to accurately capture the complexity of human progress in term of sustainability. In fact Beynon and Munday (2008) have attempt to demonstrate the imprecision and uncertainty in the EFP estimation. The thrust of the doubts of Giampietro and Saltelli (2014) pertain to the semantics and syntax of what these metrics represent and the downsides of using them for policy making. Despite the fact that these doubts have elicited debates from the scientific community (van den Bergh and Grazi, 2015), ‘business as usual’ mode of production and development cannot continue in perpetuity. In the context of the built environment, which is represented by cities and urban areas, there is a clear case to address climate change through mitigation and adaptation (McManus, 2015), which is inclusive of regeneration. The built environment of rapid urbanisation has spawned traffic fatalities, pollution of all forms, and endemic threats to human well-being (Herzog, 2015). Thus, sustainable development is a key issue for developing countries such as South Africa, who need to achieve poverty alleviation, infrastructure development, shelter for all and higher consumer expectations within added constrains imposed by ecological limits of the biosphere (Moran et al., 2008). With major carbon emissions from both existing buildings and infrastructure and on-site construction (Construction Industry Development Board, 2009), South Africa requires development without a corresponding increase in per capital demand on ecosystem resources (Moran et al. 2008). The ethics / moral of this paradigm is that most developed nations have achieved their development without such constrains - why should other nations follow a separate developmental path? In terms of the built environment, changing the behaviour of individual clients, designers and contractors, including their employees would lower the CFP through the choices that are made (Emuze, 2015).

By definition, sustainability is global, complex, comprehensive, and involves everyone, everywhere, all the time. A multi-perspectival approach review of sustainability is witnessed in the organization, Triple Pundit. Taking into considerations people, planet, and profit in regards to sustainable practices globally (TriplePundit, 2015). Responsible leadership is an

ethical approach that considers all constituents of a society and serves as a model in which leadership does not necessitate a strong top down approach to assure responsible conduct but engages at all levels of a society. Such an organization would be constituted of interrelationships that involve wide participation in robust public debate that forms a “broad and durable political consensus devised and implemented by partnerships among private firms, non-governmental organizations, municipal agencies, utilities, community groups, neighborhood groups and individuals” in other words, everyone (Hawken, Lovins, and Hunter-Lovins, 2000).

An interesting suggestion made by Rakhorst (2012) in the Dutch translation of the book *Cradle to Cradle* (McDonough and Braungart, 2002) is not to try to achieve a decrease in the things we do badly, but to try to achieve to increase the thing we do good, and green. From a pedagogical point of view, this is in alignment with a behavioristic view (Skinner, 1976). Behaviorism is the philosophy which assumes that behavior is a consequence of environmental histories of reinforcement. If the positive outcome of Carbon neutral behavior is visible, direct and sensed as resulting from one’s own choices it is easier reinforced than if the outcome’s positive effect is delayed, and not experienced as the result of one’s own doing. Of course this is going to be a difficult task in a society where we buy ready made products and the relation between the final product and the amount of energy needed for production is far from clear. Perhaps making this relation between resources and products more transparent again can contribute to change.

## **6. Conclusions**

The original intent of this research was to provide a comparative text based on CFP of each author in which the data would be understood based on equitable criteria. Then followed by an analyses of the rating systems to provide a basis for “sustainable” practices. However, as data were gathered, it became apparent that the most frequently used CFP calculator was not viable in the authors’ location because of the national bias of the CFP calculator criteria (bad).

The assumption that an understanding of the CFP (good) and knowledge of how to reduce it would be sufficient motivation for lowering the footprint was not confirmed. CFP calculators which are not globally applicable, have value in that they engage individuals in the understanding of sustainable practices at the personal level.

Those individuals with the largest footprint may not feel compelled to change the consumption patterns required to be sustainable because of the differing values (ugly) of the more affluent, regardless of nation, when using a CFP calculator.

While this realization confounded original intent of the authors, it begins to clarify the complexity that is not readily apparent when making broad and sweeping statements about sustainability, typical of such terms as “green” or “sustainable”. The prospects for change and improvement need to be carefully understood and this study begins to get the more complex issues that entail, policy, politics and ethics, at varying levels of social responsibility.



Responsible behaviour at all levels of social endeavours is a fundamental necessity for sustainable initiatives to be effective and genuine. A more critical understanding emerges when you are willing to see things from additional perspectives. From the scale of the individual to the scale of nations, if one looks to means for reducing footprint globally people are on ethical grounds to a sustainable future. It is a matter of “scale” that the CFP calculator can stimulate concern among individuals and their ability to make a difference. Oversimplification of sustainability can and has led to misunderstanding and or dismissive attitudes about the need to be responsible. Complexity and differences in evaluative criteria can provide conflicting data. The issues of how one impacts a carbon footprint are variable depending on location, history of development, population and infrastructure.

Therein lies the need for governments to provide leadership by showing courage, cooperation, fairness and moral fortitude in finding ways to change patterns to practice global enlightened self-interest for a sustainable future, as demonstrated in the COP 21 climate change summit held in Paris the week of November 20, 2015 where 40,000 delegations from 195 countries met to discuss a globally binding, nation flexible, equitable, comprehensive and durable agreement that reduces greenhouse gases emissions. The leadership of nations can serve as motivation for individuals to follow in their choices to be more sustainable, as the German Chancellor Angela Merkel remarks suggest, "billions of people pinning their hopes on what we do in Paris...Let us do everything we can not to dash those hopes," (CNN, 2015).

Awareness of consequence is a mitigating factor in creating change in personal as well as national behaviours, subjecting oneself to a CFC measure that can be comparable is a good first step in beginning a dialog between citizens and a practice that moves one towards global responsibility. It was the authors' experience that comparing own footprints and trying to genuinely explain the differences made each author more critical of the complexities and speaking to issues related to sustainability. The authors encourage involvement of other people in the same. *“Make it your business to draw out the best in others by being an exemplar yourself.” ~ Epictetus*

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# Modelling construction industries internationally, using the UK benchmark model

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## Abstract

Numerous countries produce data on the size, growth and performance of construction. Unfortunately, there is little consistency in the way construction is measured in different countries. This makes comparing and aggregating construction data difficult if not impossible. In the absence of an internationally consistent measure of construction, the UK benchmark model is intended as a first iteration of an approach to gather existing data and compare it based on common measures. The modelled data consists of total construction output, construction output by type, employment and skills and trade and output of specialist firms. This data will be useful for making comparisons with other international construction data and can be used to estimate comparisons of construction productivity and identify countries with the strongest construction industries, which may be useful in discovering countries where construction best practice exists. However, important limitations of the UK benchmark model are seen as pointing the way to further improvements of the benchmarking approach. The purpose of this paper is to set out the scope of the data that can be modelled using the UK as a benchmark and highlighting the weaknesses of the model that need to be taken into account in order to improve future international construction industry data comparisons.

**Keywords:** UK benchmark model, international comparison of construction, construction data, Gross Fixed Capital Formation

## 1. Introduction

Following the United Nations Climate Change Conference held in Paris, the Conference of Parties 21, (COP 21), in 2015 there emerged broad international agreement on the effect of climate change, (Clark and Stothard, 2015). These climate changes can be expected to impact on the construction sectors of all countries for a variety of reasons. As sea levels rise and populations are forced to move inland, where regional agriculture is no longer viable and people move into cities, expanding the size of urban populations, the implications for the global construction sector is likely to be great. The need to plan for these population movements places an obligation on policy makers to assess the amount of construction needed and the capacity of the international construction sector to meet these challenges. Economic, social, political and construction industry considerations are likely to play a major part in determining the ability of political elites to manage a peaceful, productive and creative standard of living for the global population. The scale of the problem could not be higher and the challenge greater.

If one accepts that unless policies for dealing with the consequences of climate change are developed, the cost of not acting is likely to be greater than attempting to plan for the changes when political and international tensions increase still further. Stern (2008) recognised the risks of climate change in terms

of acting to mitigate risk by reducing CO<sub>2</sub> emissions, which he equated with the kind of decisions taken when designing buildings and infrastructure. There is therefore a need to measure the extent of the problem on a global scale and this involves assessing the size, extent and location of global construction activities. To assist in this process, the purpose of this paper is to set out the scope of the data that can be modelled using the UK as a benchmark, while highlighting the weaknesses of the model that need to be taken into account in order to improve future international construction industry data comparisons that could be used to measure built environment changes as a consequence of climate change.

There is therefore an urgent need to confront the issues on a global scale. Unfortunately, there is as yet no way of comparing or aggregating national construction industries in any detail in a way suitable to estimate the potential global demand for housing, buildings and infrastructure and the capacity of the world construction industry to meet that demand. The training of labour, the materials needed and the plant and equipment as well as the costs to be managed by the public sector are all necessary to establish the scale of the problem and the policies required.

As a first step, comparable estimates of national construction industries are needed. Such information will also be of use to the private sector in terms of indicating and anticipating market changes in different countries. The public sector can also begin planning procedures, skill training requirements and the assessment of national construction industry capacities to meet demand. International bodies and funders also need the data to ensure sufficient finance is available in a timely and planned manner.

As national data is not always available in a consistent form and as it is invariably difficult to make comparisons of the national data, the use of a model is suggested to simplify the process of aggregating and comparing construction in different countries. For this reason the UK benchmark model is described here with a view to illustrating the type and scope of data that may be discussed.

## **2. The UK benchmark model**

If one adopts a pedantic approach to construction data, it will always be possible to find fault with the conclusions. Therefore in order to measure construction on a national scale let alone a global scale, it is necessary to make sweeping assumptions based on experience, knowledge and alternative sources of information. The errors and estimates built into all construction data of necessity means the data is invariably inaccurate and imprecise.

When confronted with a battery of statistics, decision-makers may respond in a spectrum ranging from accepting the data without question, to being highly sceptical of the figures and rejecting the exercise as almost a waste of time. As usual a reasoned response lies somewhere between these two extreme positions. When one examines the data in detail, how it is defined and how it is gathered, the task of capturing meaningful results becomes even more challenging. Take for example, House (2013), who describes the composition of residential data in Gross Fixed Capital Formation (GFCF) compared to housing in construction output data. Although at a cursory glance these time series may appear to be attempting to measure the same thing, they differ in several ways.

Table 1: Components of GFCF dwellings and the construction aggregate housing

<i>GFCF dwellings</i>	<i>Construction aggregate components</i>
<i>New build</i>	
New dwellings	New build output
Private housing	Private new housing
Public housing	Public new housing
Housing fees	
Self builds	
<i>Work on existing stock</i>	
Dwellings improvement	All repairs and maintenance (housing total)
Contracted improvements	
Hidden improvements	
DIY improvements	

Source: House, G., (2013) Conceptual differences between an aggregate of construction output measures and the GFCF dwellings measure, Office for National Statistics

To begin with, GFCF data covers the United Kingdom whereas the construction data only covers Great Britain. Moreover, Table 1 compares the housing components of GFCF and construction output data. While the construction output data includes all repair and maintenance, the GFCF data uses “improvements” that add to the value of buildings, of which 27% of work on existing stock (see Table 2) is classed as hidden improvements, which are based on estimates of unrecorded work or firms or individuals outside the construction industry. The GFCF figure is a measure of expenditure and includes tax and charges, which are not included in the construction output measure. The result of these differences is that one would expect the GFCF construction figures to be greater than the construction industry output figures based on the survey of construction contractors.

Table 2: Components and percentage share of GFCF dwelling components

Component of dwellings in GFCF	% of total	% of new	% of improvement
<i>New dwellings</i>	52		
of which public housing		17	
of which housing fees		0.7	
of which total private housing		82.3	
<i>Dwellings improvement</i>	48		
of which hidden improvements			27
of which DIY improvements			5
of which contract improvements			68

Source: House, G., (2013) Conceptual differences between an aggregate of construction output measures and the GFCF dwellings measure, Office for National Statistics

As estimates of hidden construction are 27% of improvements or approximately 14% of total dwellings output, it is not surprising that even official data is open to criticism and doubt. The figures are what the profession of statisticians presents and the methods used are not always understood or transparent as far as the user is concerned.

The value of annual UK construction output used in the model described here, called the UK Benchmark Model (UKBM), makes use of the official UK Office for National Statistics data. It is not necessarily accurate but may be the best estimate available. This means that it can be used to inform debate and can be used to model the construction industry, provided there is a degree of understanding that the data may not be entirely accurate. To some extent it would be preferable to have a range lying within say a

5% or 10% confidence interval rather than a single figure lying within the range. Nevertheless official data is presented with single estimates. The UKBM should be viewed as only a first iteration. The purpose of which is to communicate the scope of the research it is proposed to develop over the next two years in TG81 Global Construction Data.

The principle of the UKBM is to take the data for the UK as a guide to a number of ratios in other countries on the assumption that in the absence of evidence to the contrary, the UK ratios are indicative of the equivalent ratios in other countries. These UK ratios are used as coefficients of the national GFCF and aggregate national construction output estimates to find the total size and breakdown of national construction industries.

The following section begins by listing the official tables used in the UKBM model. They can be found in the websites of the UK Office for National Statistics and the UN Statistics Division. These form the source of data for modelling construction output enabling an analysis of types of output, type and size distribution of firms, skills and employment of construction labour. We then describe how the tables are used to build the UKBM model.

### 3. Finding the data for the UKBM model

To build this first iteration, Table 3 lists the tables used in the UKBM model.

*Table 3 Sources of data of the UKBM model*

<i>Publisher</i>	<i>Table title</i>
1 Construction Statistics Annual UK Office for National Statistics	Table 2b Construction output: volume non-seasonally adjusted – by sector
2 Construction Statistics Annual UK Office for National Statistics	Table 2.4 Value of construction output by type of work
3 Construction Statistics Annual UK Office for National Statistics	Table 2.8 Private contractors: Value of work done, by trade of firm and type of work
4 Construction Statistics Annual UK Office for National Statistics	Table 2.9 Private contractors: Value of work done by size of firm and trade of firm Values are in current prices.
5 Construction Statistics Annual UK Office for National Statistics	Table 3.4 Number of firms by size and trade of firm
6 National Income Accounts Office for National Statistics	Table G8, Gross Fixed Capital Formation by sector and type of asset
7 UN Statistics <a href="http://unstats.un.org/unsd/snaama/dnlList.asp">http://unstats.un.org/unsd/snaama/dnlList.asp</a>	UN Data Table “GDP and its breakdown at constant 2005 prices in US Dollars” (All countries)

Because it is difficult to locate specific spreadsheets in the UN database, the following advice is given. For the purposes of accessing data for the UKBM model, the UN url is given in Table 3 above for the UN Data Table. This will direct the reader to the UN National Accounts Main Aggregates Database. From there, select “GDP and its breakdown at constant 2005 prices in US Dollars.” From the list select the country and then “Gross fixed capital formation (including acquisitions less disposals of valuables)” for the country selected.

## 4. The UKBM model

The purpose of the UKBM is to find a consistent international measure of construction output and other construction variables, such as the size of markets for various building types, number and types of firms, numbers employed and skills. This will provide a data base of estimates of the size and growth rates of all national building industries, a breakdown of different types of buildings and structures, the number and types of firms, numbers employed and skills. This will in turn provide time series of various national and sub-national variables, including estimates of capacity, size of markets and growth rates.

The basic UKBM model estimates total annual construction output and size of types of work. A second model, not discussed here, will model firms, skills and employment. What follows is a statement of the method used to build the model.

In order to link the construction industry measures of the national construction industries of all countries, GFCF is used as this is comparable for all countries and is published by the UN Statistics Department. The theoretical definition of GFCF is the value of capital formation before depreciation. The GFCF figure includes new build dwellings and other new buildings and new build structures but the size of the construction industry is measured as the total of new build *and* repair and maintenance. As repair and maintenance (R&M) is maintenance of existing buildings it is a form of depreciation or capital consumption, which is not included in GFCF in principle. We therefore assume only new build is included in GFCF. To include repair and maintenance to find total construction output, an adjustment to the built element of GFCF is needed. The UK benchmark model therefore adjusts the new build construction element of GFCF by adding an estimate of R&M. This is achieved using the following steps:

1. To find the average ratio of new build to total build 1997-2014 access Table 2b “Construction output: volume non-seasonally adjusted – by sector” in the Office for National Statistics construction statistics series.
2. Use the inverse of the ratio in step 1 to multiply each year’s total built element in GFCF in Table G8 “UK GFCF by sector and type of asset” not seasonally adjusted, chained volume reference year = 2011. This forms an estimate of annual total construction, including R&M.
3. Use total UK construction calculated in step 2 to estimate the average ratio of the total construction to UK GFCF between 1997 and 2014 or any other appropriate years.
4. Use the average ratio found in step 3 as the co-efficient of the UN annual GFCF for specific countries selected in the UN table entitled “GDP/breakdown at constant 2005 prices in US Dollars (all countries)”. This is the UK benchmark estimate of the value of specific country’s annual construction outputs.

The size of construction for any country can be modelled from UN GFCF using the ratio of the UK built element in UK GFCF over UK GFCF as a benchmark co-efficient. The modelled data given here is construction output 1970 to 2013. This is based on the average ratio of new build to total UK construction output data for 1997 to 2014, the average ratio of the UK built component of GFCF over GFCF for the period from 1997 to 2014 and UN GFCF data for 1970 to 2013.



## 4.1 Limitations of the UKBM model

According to the OECD, (2014) gross capital formation includes spending on additions to fixed assets, such as the construction of roads, railways, offices, industrial buildings, hospitals and residential dwellings. According to the OECD, data on construction capital formation is equivalent to data on construction activities. The reliability of data, the OECD warns, depends on the quality of government accounting systems and these are often weak in developing countries. Measures of fixed capital formation by households and firms, especially by small enterprises, can be inaccurate.

The UKBM model assumes the ratios of the UK can be transferred and applied to other countries. However, the UK is not necessarily representative of the countries shown. According to OECD (2014), Table 4 compares buildings and structures as a percentage of GFCF in 31 countries for the years 2001 and 2011.

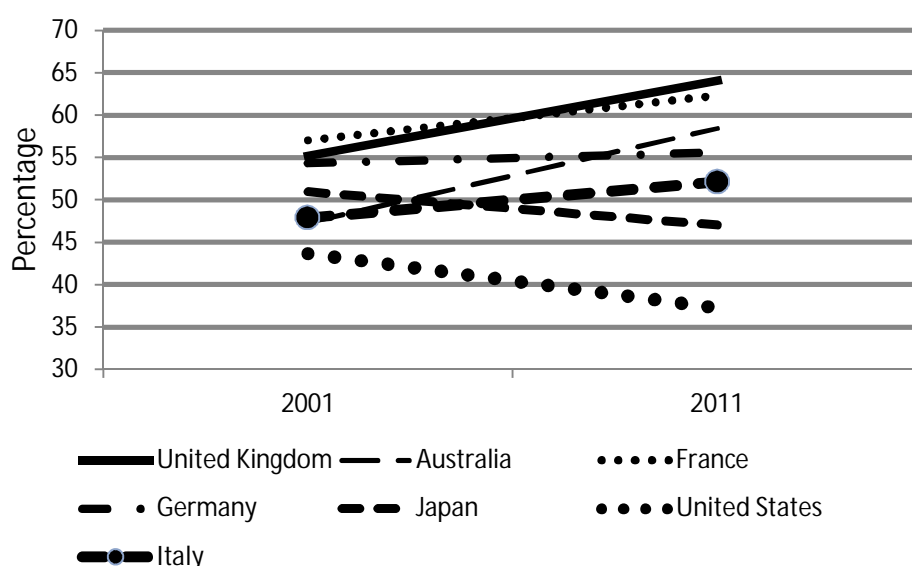
*Table 4: Change in percentage of built component of GFCF 2001 and 2011 for 31 countries.*

<i>Country</i>	<i>2001</i>	<i>2011</i>
Australia	47.35	58.49
Austria	53.73	51.92
Belgium	46.91	54.91
Czech Republic	45.56	50.07
Denmark	49.56	50.89
Estonia	50.24	50.50
Finland	61.19	68.22
France	57.06	62.34
Germany	54.31	55.65
Greece	65.19	52.64
Hungary	50.26	52.12
Iceland	61.20	54.34
Ireland	68.99	53.65
Israel	49.78	52.08
Italy	47.89	52.14
Japan	50.96	47.08
Korea	57.44	57.96
Luxembourg	51.83	56.77
Netherlands	56.55	56.26
New Zealand	47.47	55.56
Norway	63.17	69.00
Poland	56.20	62.04
Portugal	62.23	61.41
Slovak Republic	46.86	45.14
Slovenia	52.20	49.71
Spain	66.35	62.39
Sweden	38.03	43.52
Switzerland	41.07	45.33
<i>United Kingdom</i>	<i>55.27</i>	<i>64.11</i>
United States	43.72	37.25
South Africa	33.74	48.47

Source: National Accounts at a Glance 2014 - © OECD 2014, Chapter 3 Table 10.2. Gross fixed capital formation by asset Version 1 - Last updated: 30-Jan-2014

Examination of the data shows that the average based on the geometric means of the countries in Table 4 in 2001 and 2011 were 52.00 and 53.79 respectively. The UK stood at 3.27 above the mean in 2001 and 10.32 in 2011. This meant that the UK was 0.39 of 1 standard deviation above the mean in 2001 and 1.44 standard deviations above the mean in 2011. This represents a large relative share increase of GFCF of the UK construction industry compared to the construction industries of the other OECD countries listed and implies that the UK industry was not typical of the relative performance of the other countries in 2011.

Figure 1 shows the change in the size of construction compared to GFCF in 7 mature economies at a similar stage of development to that of the UK. The performance of the UK construction industry relative to investment in plant and machinery shows that in the UK the share of construction in GFCF grew faster in the UK than it did in the other comparable economies. This of course could be due to changes in the amounts invested in plant and equipment as much as increasing investment in construction in the UK. At the very least it reflects changes taking place in all these economies following the global financial crisis which began in 2007.



*Figure 1: Changes in percentage of built component in GFCF 2001 – 11 of 7 selected countries*

Source data for Figures 1-5: National Accounts at a Glance 2014 - © OECD 2014, Chapter 3 Table 10.2. Gross fixed capital formation by asset Version 1 - Last updated: 30-Jan-2014

Figure 2 shows the UK to have a greater proportion of construction in GFCF than the average for the other 31 countries compared in Table 4 or even the 7 selected countries shown in Figure 1. This data shows that the performance of the UK during the period between 2007 and 2011 may have influenced the results rather than the performance of the construction industry alone. The UK economy recovered and managed to recover faster than the other countries during an exceptional economic crisis. Further research is needed to assess the performance of construction in detail over a longer period.

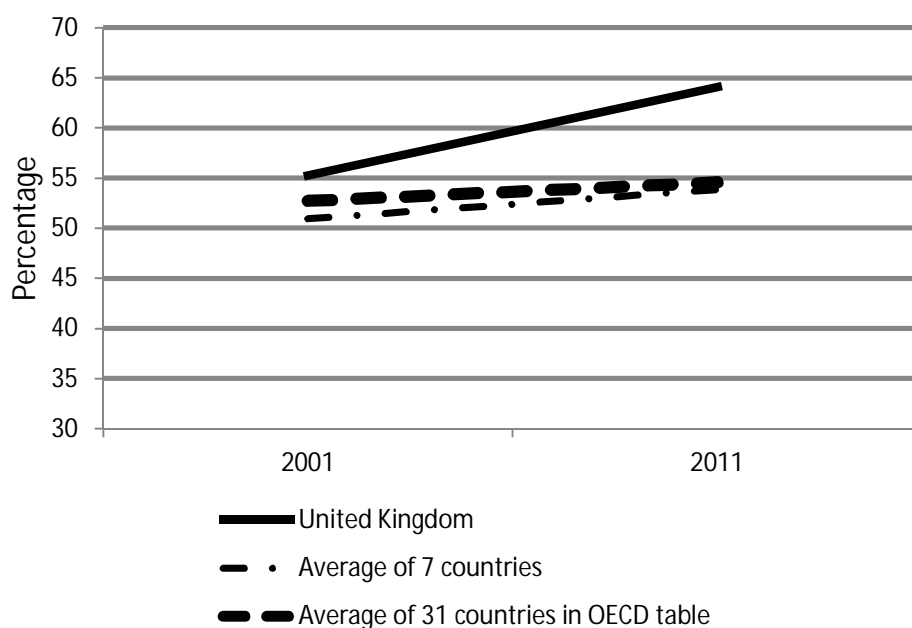


Figure 2: Changes in percentage of built component in GFCF 2001 and 2011

The differences between the UK and the other countries compared in Table 4 demonstrate that the UKBM model needs to be used with caution. Nevertheless, from the UKBM model covering the period from 1970 to 2012, two differences emerge compared to the official UN data sets. First, size of the construction sector in the UKBM model is much greater than the ISIC figures for the same years published by the UN. Secondly, the UKBM shows a higher growth rate than the International Standard Industrial Classification (ISIC) data of the construction industry. Examples of these results can be viewed in Figures 3 to 5 for the US, the UK and Japan. These results raise several issues and questions. Is the difference in size significant? Are the differences in growth rates significant? Which set of data supports which theories? Did global construction see an expansion since 1970? Or has the construction industry as a whole stagnated over the last 40 years?

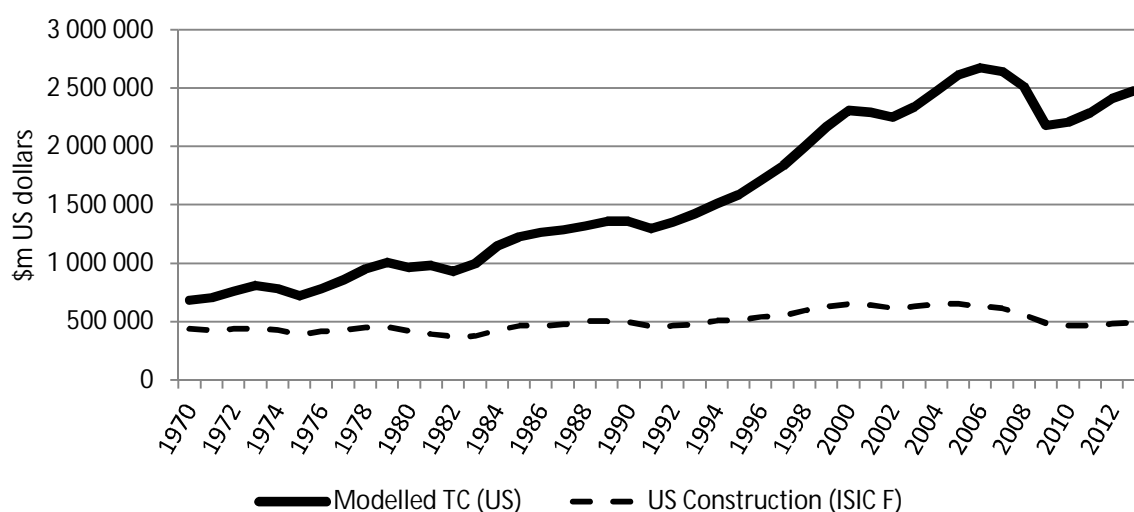


Figure 3: United States ISIC F Construction and the UKBM for construction output 1970 to 2013

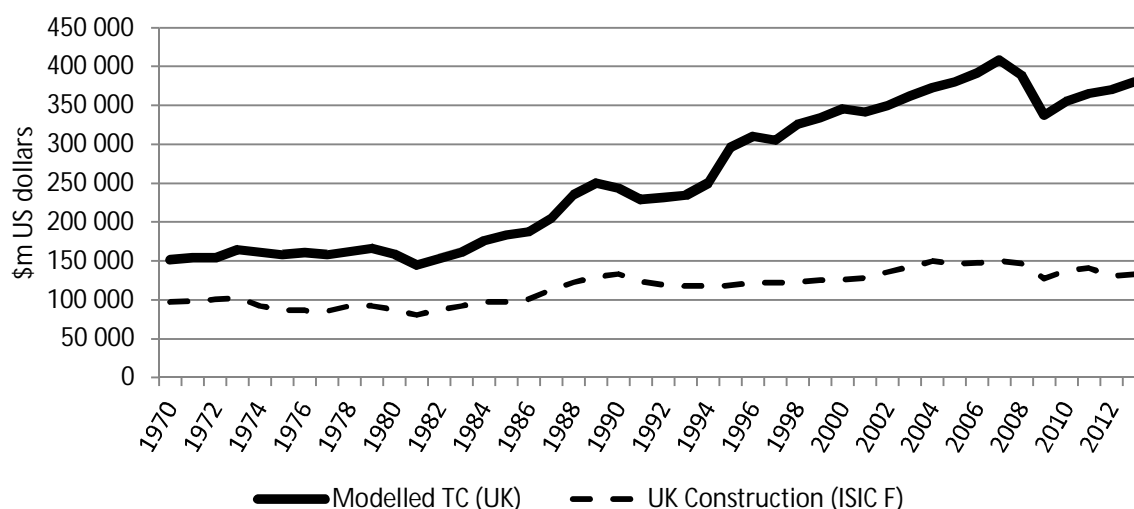


Figure 4: United Kingdom ISIC F Construction and the UKBM for construction output 1970 to 2013

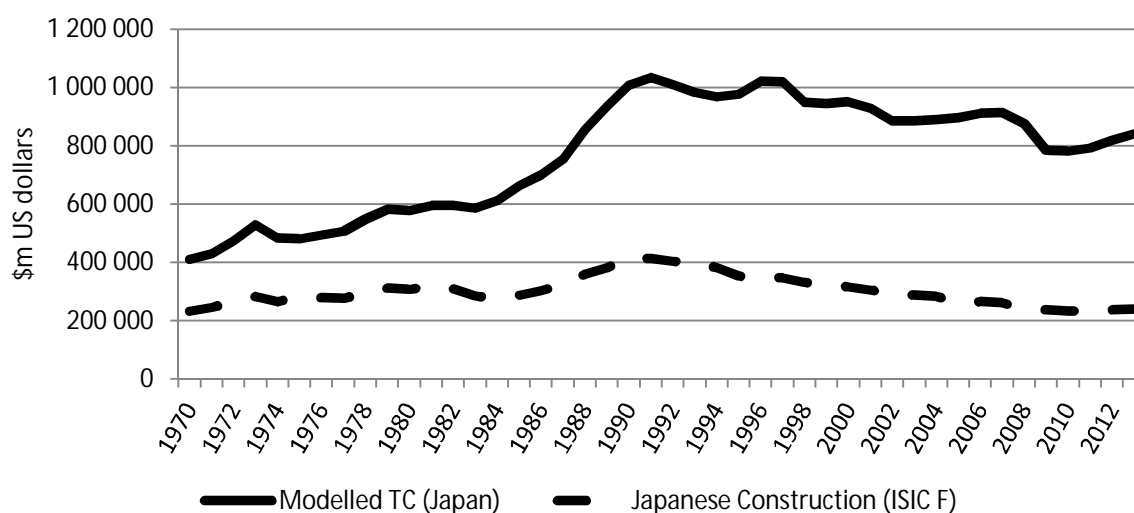


Figure 5: Japan ISIC F Construction and the UKBM for construction output 1970 to 2013

## 5. Concluding remarks

The UKBM is a first iteration of a model to find a consistent approach to measuring construction industries internationally. One feature of the UKBM model is that it treats all countries in the same way, making it possible to compare results as the methodology is consistent. However, this method has shown that using one country as a benchmark to base the coefficients of the model is too simple and too dependent on one country and the performance of its construction industry.

The limitations discussed above point to the need to either establish a basket of countries to form an average benchmark or to develop different benchmarks for different regions of the world or different economies at different stages of development.

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# Factors influencing the renegotiation of public-private partnership road projects

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## Abstract

A critical evaluation of recent literature reveals that there is evidence of a high incidence of renegotiation in public-private partnership (PPP) infrastructure projects, particularly in the road sector. This high incidence of renegotiation in road projects can be attributed to a number of factors, which influence the decision of the primary stakeholders to renegotiate the contract. Based on this prevailing situation in PPP road projects, this paper evaluates and assesses the factors influencing the renegotiation of PPP road projects. An exploratory research method involving a comprehensive literature review of PPP road projects was adopted. The findings of the study indicate that the factors influencing PPP road projects fall under design, economic, technical, institutional, regulatory, contractual, administrative and managerial, political, social and environmental categories. The paper concludes by identifying the factors, which have profound influence on the renegotiation of PPP road projects. These can be classed as design, regulatory, administrative, and technical factors in their respective order of literature prominence. The development of modalities to assess and ensure the credibility of PPP regulation and the proper estimation or evaluation of PPP road projects at the design, technical and administrative/managerial levels are recommended.

**Keywords:** Critical factors, renegotiation, public- private partnership, road projects and transport sector.

# 1. Introduction

Previous theoretical and empirical studies investigate contract renegotiation of PPP projects by investigating the incidences and influencing factors among others. Furthermore, notable studies across countries provide a summary of PPP infrastructure projects renegotiation, particularly in transport projects. Evidence from numerous renegotiation studies in Latin American countries as well as Portugal and Spain, reveals the characteristics of the respective cases of renegotiation. An examination of these cases reveals that the stakeholders involved in PPP infrastructure projects usually have reasons for the renegotiation of projects at strategic implementation points.

Given that the renegotiation of road projects is usually premised on the reasons identified by the public agency and private concessionaire, which may also be regarded as the motive of the parties to the contract. Hence, there are numerous reasons why stakeholders may want to renegotiate a contract in a PPP environment which may sometimes be distinct from the drivers of the renegotiation. However, what influences the decision of the stakeholders to renegotiate the contract is the subject of this discussion. These influence factors require in-depth and critical evaluation in order to arrive at appropriate answers with regards to the factors influencing PPP road project renegotiation. The clear reason for carrying out a critical study on this subject is the dearth of comprehensive literature in this area. Thus, this paper evaluates and assesses the factors which can positively or negatively influence the outcome of PPP road project renegotiations.

## 2. Overview of the Renegotiation of Transport Sector Projects

Road projects constitute significant means of transportation in developed and developing countries (Gor and Gitau 2010). Indeed, it has been procured on the basis of PPP across and has demonstrated a high percentage of renegotiations in many countries, e.g. Latin America and the Caribbean (Bitran et al., 2013), US (Gifford et al., 2014), Portugal (Sarmiento, 2014), Spain (Baeza and Vassallo, 2010) and Greece (Nikolaidis and Roumboutsos, 2013). Examination of 254 renegotiations in Portuguese infrastructure projects reveals that the road sector accounted for 233 cases which ended with compensation to the private company (Sarmiento, 2014). In Latin America, experience reveals that 54.7% of transport concession contracts awarded were renegotiated and mostly benefited the concessionaires (Guasch, 2004). Furthermore, Engel et al. (2009) note that the Chilean experience reveals that firms lowball their offers, expecting to break even through renegotiation. Governments also use renegotiations to increase spending and shift the burden of payment to future administrations. Thus, renegotiation of these concessions thus results in increases in the future costs of service for users.

Moreover, Reside and Mendoza (2010) appraise the Asian experience and reveal that about 70% of PPPs are renegotiated, which in most instances results in increased subsidies and financial compensation for the concessionaire companies. Renegotiation of PPP projects also tends to be unfavourable to the public sector in the United States of America (Gifford et al., 2014). Summarily, the study of Fatokun et al., (2015: 1254) review renegotiation issues and outcomes and agrees with the findings of these literature that *“most PPP projects, and particularly road projects are highly renegotiated and analysis of the renegotiation of PPP road projects across*

*notable countries revealed that value for money (VfM) is not achieved for the public sector in most cases”.*

Therefore, the high incidence of renegotiation in PPP road projects needs to be reviewed and investigated in order to identify the factors which influence contract renegotiation. Hence, the aim of this paper is to as far as possible elaborate on the findings of the previous paper i.e. (Fatokun et al., 2015) in order to fill the vacuum in knowledge through a thorough evaluation and explanation of renegotiation influence factors in PPP road projects. What is striking is the way the respective sub-factors are categorised under the main category, which relates to the respective phases of implementation. Obviously, the renegotiation of PPP road projects has been found to be influenced by several factors.

### **3. Research Methodology**

This paper is based on a review of recent literature, most of it published within the last ten years and whose content were analysed systematically in line with the recommendation of Guasch (2005) for an extensive study to further the understanding of the various renegotiation issues in PPP projects (including roads). These issues are related to pre-concession, concession design and award, regulatory, institutional, economic/technical and administrative procedures. The review was done through an evaluation of twenty-three academic papers of which most were journals. It was observed that the factors which influence PPP road projects renegotiation fall under these issues. In addition, the review lead to the identification of fifty-two factors categorised into ten groups, all of which have influences on the renegotiation of PPP road projects. These categories elaborately delineate the underlying factors which encompass and extends beyond the related issues identified by previous studies as having influence on PPP road projects renegotiation.

### **4. Factors Influencing Renegotiation of PPP Road Projects**

Many reasons and advantages have been adduced for the adoption of PPP. However, in spite of the reasons and advantages claimed for the adoption of PPP in infrastructure project delivery (including transport projects), this procurement method has over the years witnessed setbacks due to factors constraining its successful implementation. These factors include issues relating to incomplete contracting, project abandonment, cost and time overruns, and renegotiation among others (Guasch et al., 2014; Domingues and Zlatkovic, 2014; Nikolaidis, and Roumboutsos, 2013). However, one of the major factors is the renegotiation of PPP contracts (Cruz and Marques, 2013; Estache et al., 2009). The factors influencing the renegotiation of PPP projects can, therefore, be classified as design, contractual, technical, institutional, regulatory or legal, environmental, economic and social, etc. Table 1 shows in detail the respective sub-factors under each of these headings, giving the respective sources of the papers in which they are discussed.



Table 1: Factors Influencing the Renegotiation of PPP Road Projects																								
Influencing factors	Publication/Source																							
	Cruz et al. (2015)	Guasch et al. (2014)	Dominiques & Zlatkovic (2014)	Bitran et al. (2013)	Cruz & Marques (2013)	Menezes and Ryan (2015)	Bi and Wang. (2011)	Montecino & Saavedra(2011)	Baeza & Vassallo (2010)	De Bruix (2010)	Reside & Mendoza (2010)	Chan et al. (2010)	Saussier et al. (2009)	Athias & Nunez (2008)	Estache et al. (2009)	Guasch et al. (2007)	Engel et al. (2009)	Guasch & Straub (2009)	Guasch (2005-2004)	Estache et al. (2003)	Guasch et al. (2004)	Sarmiento (2014)	Number of Citations	
Design factors																								
Change in concession design scope					✓																	✓	2	
Inaccurate estimation of traffic level	✓	✓	✓					✓	✓														5	
Misallocation of traffic risk		✓	✓					✓	✓												✓		5	
Inaccurate estimation of capital cost									✓														1	
Poorly written contract (ambiguity)		✓	✓							✓									✓				4	
Technical factors																								
Unilateral changes of design concept during project execution	✓				✓																		2	
Variations or additional works																						✓	1	
Specification changes during technical development of projects		✓		✓	✓																	✓	4	
Efficiency or standard of technical skills and expertise											✓												1	
Delays during project execution																						✓	1	
Economic factors																								
Changes in economic policy		✓						✓						✓					✓				4	
Changes in general price level		✓			✓																		2	
Change in demand		✓				✓																	2	
External or macro-economic shock				✓			✓				✓				✓						✓		5	
Weak economic environment											✓											✓	2	
Contractual factors																								
Defective contract award criteria/ incorrect contractual assumptions											✓								✓	✓		✓	4	
Contract characteristics															✓								1	
Inadequate contract mgt. expertise or knowledge															✓								1	
Use of multidimensional auctions													✓										1	
Effectiveness and efficiency of contract enforcement									✓				✓						✓	✓		✓	5	
Delays in expropriations	✓				✓																	✓	3	





results of these factors are time and cost overruns, which may necessitate the renegotiation of the contract duration and the contract sum respectively (Guasch et al., 2014; Sarmiento, 2014). Thus, technical factors such as errors or omissions during construction could impact project objectives and ultimately lead to a revision of the agreed contract sum and an extension of the concession.

Economic Factors: Significant changes in economic circumstances, e.g. changes in economic regulation by the government with respect to exchange rates, currency valuation (i.e. devaluation and appreciation or) other financial policies etc., can drive renegotiation of PPP road projects (Montecino and Saavedra, 2011; Athias and Nunez, 2008). These changes have the tendency of positively or negatively influencing the renegotiation of PPP road projects during the implementation process prior to the completion and transfer of the facilities to the government. Therefore, unexpected changes in the economy could influence contract renegotiation.

A renegotiation could also occur as a result of the abuse of the financial equilibrium principle stated in the contract. For instance, the non-adherence to the defined financial budget and contract sum in accordance with the provision of the contract could necessitate renegotiation of PPP road projects. Furthermore, changes in the price of commodities, e.g. materials, labour and equipment, could result in the renegotiation of the contract. A change in demand for PPP products could also influence renegotiation of PPP projects (Guasch et al., 2014). Therefore, there could be a renegotiation of PPP road projects in a situation where there is a shortage of funds or the bankruptcy of the private concessionaire during the PPP road project implementation.

Contractual Factors: Incorrect assumptions in contract agreements may lead to the renegotiation of PPP road projects (Reside and Mendoza, 2010). These assumptions could relate to an incorrect risk sharing ratio or matrix, the improper allocation of responsibilities to the contractual parties, and erroneous specifications and clauses, etc. Errors in any of these areas could influence the renegotiation of the PPP contract at any stage of project implementation. The characteristics of the contract may also influence renegotiation (Estache et al., 2009). These may have to do with how realistic and accurate the contractual agreement is with respect to the concession period, contract specifications and the main and subsidiary objectives of the parties.

Moreover, the effectiveness of the way the contract is enforced influences PPP renegotiations (De Brux, 2010; Athias and Nunes, 2008; Guasch, 2005). The need for effective and efficient contract enforcement by the respective government agencies and designated consultants in the management of the contract cannot be over-emphasised. Delays in expropriations are one of the types of delay which may cause the renegotiation of PPP road projects (Cruz et al., 2015). The intensity of the delays experienced in terms of its length or duration has resulted in serious renegotiation problems due to the impact on cost and time variables.

Administrative and Managerial Factors: It is a key administrative and managerial responsibility to assess bids at the tender evaluation stage of a PPP road project in order to identify opportunistic and aggressive submissions, and failure to do this may lead to the renegotiation of the contract. The usual result of the poor evaluation and assessment of aggressive or opportunistic bids is that the initial contract sum submitted is inadequate, which means that the need usually arises for the renegotiation (usually upward review) of the PPP contract sum during project implementation in order to successfully complete the PPP road project (Fatokun et al., 2015).

Corrupt practices in the management of PPP road projects also play a significant role in the renegotiation of the contract. Country-level and firm corruption has been identified as a significant determinant of renegotiations. A more corrupt environment clearly leads to more firm-led renegotiations and significantly reduces the incidence of government-led ones (Guasch et al., 2014, Guasch and Straub, 2009). In contrast, less renegotiation occurs in an environment where corruption is less prevalent. Corruption manifests itself in several ways during renegotiation. First, renegotiation can be used as a good opportunity for governments to bypass the due process required for securing additional financing or authorization of increased investment (Guasch et al., 2014, Engel et al., 2009). Also, there may be collusion among the tenderers to increase the contract sum. Finally, administrative delays, which may be due to bureaucracy and human-related problems, are all examples of corruption, which may result in renegotiation.

Institutional Factors: There has been evidence of renegotiation of PPP projects as a result of misaligned institutions and the corporate decisions taken during the implementation of PPP projects (Guasch et al., 2014). These decisions may influence the renegotiation of PPP road projects. Nevertheless, corporate and regulatory institutions are vital to the sustenance of PPP. However, research has found that the inadequacy or lack of regulatory institution is one of the factors influencing the renegotiation of PPP road projects (Bitran et al., 2013). Thus the unavailability of institutions which can provide adequate corporate governance and administration of PPP projects has been identified as one of the factors influencing the renegotiation of PPP projects.

Regulatory and legal Factors: Specific changes to the legal framework, poor regulation and the lack or inadequacy of regulatory accounting could influence PPP renegotiations (Sarmiento, 2014; Montecino and Saavedra, 2011). Also, non-transparent regulatory frameworks and processes for the renegotiation of PPP infrastructure projects can be attributed to the series of renegotiation experienced. These legal dimensions could necessitate specific changes to the terms and conditions of the PPP agreement or lead to the introduction of additional clauses to modify the scope of the original PPP road concessions contract. Hence there should be an understandable, well-defined and strong regulatory and legal framework, which spells out the modalities for contract renegotiation in order to reduce the negative influence of PPP renegotiation, as a weak regulatory and legal environment may easily lead to legal and regulatory changes, which ultimately encourages contract renegotiation.

Political Factors: The political situations such as a change in government or changes in the priorities of the government could influence the renegotiation of PPP road projects. A change in government may result in changes in policies and priorities which could manifest themselves in new areas of concern or investment in PPP infrastructure projects. Thus a need to renegotiate existing or ongoing PPP road projects may emerge as a result of the change in the political situation. Electoral cycles and the awarding of concession contracts shortly before or shortly after an election could also influence the renegotiation of PPP road projects. Different governments have different agendas during their term of office, with different cardinal objectives, which in turn guide their procurement decisions. Thus, the terms of ongoing PPP projects awarded by a previous government may not be aligned with the objectives of a new government and may therefore be discarded and replaced with new objectives.

Any motive to achieve new political objectives usually influences renegotiation of previously agreed PPP road contracts.

Environmental Factors: Some environmental factors drive renegotiation of PPP road projects. These factors have a bearing on the outcome of the projects and include all external conditions or influences on development projects. It has been observed that construction project development may be impaired by a lack of good knowledge and successful management of the impact of the environmental factors, which may influence the performance of such projects (Akanni et al., 2015). Thus, the impact of the environment on the successful implementation of PPP road projects cannot be over-emphasised. Environmental factors in this regard encompass but are not limited to all physical influences in the environment within which a construction project is sited. The geographical location of a project, ground conditions and weather patterns, etc. are environmental factors.

Notable PPP studies have identified changes in design as a result of environmental requirements as one of the factors influencing the renegotiation of PPP road projects (Cruz et al., 2015; Sarmento, 2014). These changes may be expedient in a situation where it becomes practically impossible to continue the construction of PPP road projects as a result of environmental problems and challenges impacting on them (Cruz et al., 2015; Menezes and Ryan, 2015). Furthermore, the impact of weather conditions (e.g. rain and sunlight), as well as archaeological finds, could cause obstacles to the continued construction of a road project (Menezes and Ryan, 2015). Such circumstances may, therefore lead to the renegotiation of PPP road projects.

Social Factors: The social acceptability of PPP road projects characteristics as well as the acceptability of the accruable cost or the degree or readiness of potential users to pay for the services provided has been examined by several scholars (Domingues and Zlatkovic, 2014; Guasch et al., 2014; Sarmento, 2014; Baeza and Vassallo, 2010). This situation has raised concerns about the ability of PPP to deliver the objectives of users and taxpayers in terms of value for money (VfM).

Adair et al. (2011:9) comment on these social concerns: “the rollout of the public-private partnership models has not met with universal approval; indeed in some countries there has been strong resistance to public-private partnerships with misgivings centred on the level of private sector profiteering as well as long-term obligations placed on the taxpayer”. This confirms that the poor level of users’ satisfaction is responsible for non-acceptance of PPP for infrastructure project delivery and provision of social services across countries. Indeed, the acceptability of PPP in the provision of social services has been strongly resisted in some countries through various means including industrial action. This resistance has led the governments of countries to provide subsidies to reduce charges and taxes imposed on road users.

## **5. Conclusions**

The literature reviewed here has succeeded in categorising the various factors which could influence the renegotiation of PPP road projects, and identify the respective influences. The results of the review indicates that the design, regulatory, administrative, political, contractual,

and economic factors have various sub-factors in their respective categories. Many authors agree that the following design-related factors influence the renegotiation of PPP road projects: misallocation of traffic risk, over/underestimation of traffic levels, defective contract award criteria or incorrect contractual assumptions/design, poorly written contracts (concession). Furthermore, regulatory and administrative factors follow design factors in the extent of the influence they exert. However, the sub-factor which exerts the most influence of all is inadequate or non-existent regulatory account (arising from the non-existence or weakness of a regulator), which is a regulatory factor. Other regulatory sub-factors, which can also be considered critical are the type of tariff regulation, including governance and regulatory effectiveness among others.

In conclusion, the renegotiation of road projects in a PPP environment is mostly attributable to design and regulatory factors. Although, there is a need for further qualitative or quantitative studies which should be methodologically analysed to establish and ascertain the criticality of these factors. In addition, there is a need for a proactive strategy to be developed in order to tackle the influence of the factors in each of the categories identified so as to promote profitable and positive renegotiation results. This strategy may necessitate the development of modalities to assess and ensure the credibility of PPP regulation, which will guide PPP renegotiation in the road sector. Also, proper design of concessions to ensure the elimination or reduction of the level of incorrectness and inaccuracies in the process will go a long way to reducing the negative influence of the factors identified. Finally, there is a need for greater transparency and due diligence in PPP, particularly at the pre-concession or bidding stage, in order to reduce the level of corruption and opportunistic behaviour on the part of the contracting parties.

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# Identification of vacant space; a prerequisite for industrial and societal development

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## Abstract

In the real state community, vacant space is mostly regarded as a cost and a negative factor. However from a societal perspective, vacant space might function as a necessity for growth and creativity. Vacant space is not merely relevant for companies and organisations, but also for residential areas. In order to satisfy space flexibility, companies and organisations must have access to additional space during periods of expansion as well as additional residential areas and other facilities for e.g. employees. Conversely, vacant space must be managed during times of recession. In current practices, space flexibility can be enhanced through efficiencies, ownership, relocation, leasing, and in a larger scale, through governmental and public initiatives. This paper presents new methodologies derived from strategies from manufacturing industry; which are here applied to identify vacant space and potential market. It has been discussed a certain amount of concepts for an efficient allocation of resources by relating to Facilities Management, Total Quality Management and ICT as a significant approach for rendering efficiencies in land use, particularly in countries characterised by scarcity of green areas and abundant “brownfields” are rather a topic for development. In a conclusive discussion, this paper argues that the identification of vacant space, in multiple perspectives, is crucial for the future for urban and regional planning.

**Keywords:** vacant space, development area, manufacturing methodology, Kano model

## 1. Introduction

How can various kinds of vacant space best match the various needs of users and stakeholders? Vacant space is generally regarded as a negative factor among investors in particular. However vacant space could as well be regarded as a resource. At the Facilities Management Master Course 2000 to 2003 at Chalmers University of Technology and at the Real estate management Master course at Politecnico of Milan the value of spatial vacancy was widely discussed and emphasized among the participating professional facilities managers; indeed vacancy during the discussions was not merely regarded as a negative factor for owners in particular, but also a necessity. Refurbishment at a hospitality plant, for

example, must use vacant space by enabling continuous move of various sections of the hospital. Furthermore, in the ideas of dynamics of space use, growth firms for example have an advantage if they can expand to adjacent vacant spaces with permanent or temporarily leasehold contracts and maintaining a core of space for long term core activities. Studies in the industrial suburbs of Northern Italy, specifically in the Lombardy Region, render similar conclusions; the networks of entrepreneurial and manufacturing firms are dependent to access vacant space due to market fluctuations and demand for manufactured products. Having a close relation to business cycles, firms must as a consequence have a dynamic relation to space use and its facilities management. The management of space use can to a certain extent, become rendered more efficient and thus postpone decisions on expansion or full or partial relocation (Ciaramella and Dettwiler, 2012). Several consultancy firms measure frequently vacancy rates for benchmarking, forecasting and analysis of business cycle trends and real estate markets (often office space and retail space).

As a contribution on research and discussion on spatial occupancy, this paper aims to explore the nature of vacant space and the value of identifying various spatial categories that would more efficiently match the complexity of needs through means of ideas and methods from manufacturing industry.

## **2. Vacant space a significant parameter of our society**

Who owns the vacant space? Suburban and urban space was a political issue after the Second World War when some philosophers and sociologists regarded new construction spaces as a common good and having primary purpose to satisfy human interaction (Lefebvre, 1968 and Bourdieu, 1984). Promotion of interaction in public areas gave 20<sup>th</sup> century influences on architecture and urban design (Gehl, 1987 and Hillier and Hanson, 1984 and other) which gave a balance of the physical artefacts (buildings and infrastructures) to the actual activities within urban spaces consisting of interaction and various services.

In recent years, conjoint with the debate on sustainability, houses and areas with development areas often become focus for new lifestyles, energy saving and even local food production. Still vacant areas needs financial means for development where public finance only covers the new constructions and refurbishment partially. Conjoint with the real estate crises in the beginning of 1990<sup>th</sup>, with a multitude of bankruptcies where the ownership was transferred to public entities, the idea of Private Public Partnership (PPP) become a solution; in order to develop abandoned buildings and areas; private interests were interweaved with public interests. Often a balance must be sought between private and public interest for development of vacant space. Vacant space has both negative and positive features; is a resource for governments to create so-called clusters and industrial development.

The occupancy oscillations due to business cycles with its dynamic forces between boom and recession are mirrored as well in the real estate market. Jong Lang Lasalle (<http://www.jll.com/>) illustrates the phenomenon as an “office property clock” by placing different cities around the world on upturn and downturn trends on office property market. Still, occupancy in these measurements are regarded ubiquitously a something positive, whereas the counterpart, vacant space is generalised as a negative factor.

The notion of natural vacancy has a significant role in Real Estate Economics as an intermediary factor between supply and demand. In fact, lag effects can be observed between cycles; demand and supply of office space (Pyhr et al. (1999), Gabriel and Nothaft (1988), Whaeton (1990) and Sanderson et al. (2006)). Vacancy of office space is not only associated to acquisition or leasing but also to the

problematics of location and service like facilities management. Additionally to the mentioned lag effects in real estate occupancy can also be observed in a facilities management perspective, where the use of office space and connected services does not follow simultaneously the fluctuation of GDP (Growth Domestic Product/Capita) probably because firms are contractually bound to previous periods (Dettwiler, 2008).

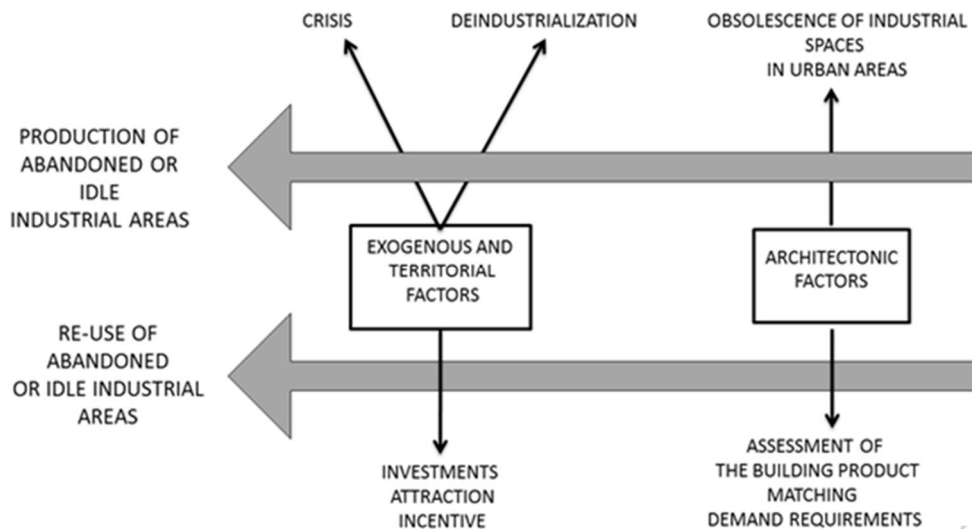
Reasons for vacant space have multiple reasons. In Europe vacant spaces is related to industrial areas for primary and secondary industries that have ceased or relocated their activities, so-called “brownfield” (CABERNET, 2015) that additionally often have contaminated soil, which implies considerable decontamination costs for successive constructions (Ferber *et al.* 2006).

In global perspective, the reasons for spatial vacancy have numerous exogenous factors e.g.:

- **Obsolescence:** Building themselves might not meet the needs or the, abundant areas activities have become obsolescent; e.g. manufacturing plants, military buildings and hospitals
- **Competition:** Location in general might have lost the attractiveness. Other areas are more attractive in terms of price, image, infrastructure, nearness etc.
- **Destruction:** The remains of old construction and contamination of soil makes it difficult (often due to protection of cultural heritage) and expensive to incorporate new structure
- **Force majeure:** Political and global market forces e.g. former communist states, Detroit automotive industry etc.

The interrelationship between relationships of factors might favourably be illustrated in a figure than simple enumeration of separated factors (Figure 1). The production of idle or abandoned industrial areas can be regarded as a mix of exogenous factors such as the global crisis and the deindustrialization and architectonic factors; and additionally such as the obsolescence of industrial spaces in urban areas.

Two interdependent parallel processes influence the extent and use of idle or abandoned industrial areas namely; (1) addition or “production” of new space and (2) re-use of vacant space. The challenge is to manage the themes of performance, obsolescence, life cycle of industrial spaces and infrastructures thorough analysis of needs of the modern industry. Considering which type of manufacturing that can be hosted by modern cities, and in the same time to meet modern requirements, would be to establish a sustainable renewal process of idle and abandoned industrial areas for manufacturing and production (Figure 1). For planners and architects, the ultimate challenge is to provide appropriate spaces to modern industries with an understanding of the complex circumstance of present and future production.



*Figure 1: Key Factors and production of idle/abandoned industrial areas (Celani 2015, European Architects Network annual seminar, Milan, October, 17th 2015)*

Furthermore, the challenge is to assess physical nearness standards to building categories of residential and tertiary sector areas. Most countries have zoning policies that prohibits residential planning in manufacturing zones. However with the emergence of manufacturing industry with “clean” production, many modern industries of today can be regarded as a part of tertiary sector. In urban planning the urge for attaining higher congestion, mixture of dwellings and workplace in the same area tend to be accepted. Interestingly, such mixture would be a comeback to the old European urban structure.

### 3. Inspiration from industry; methodologies

Considering that vacant spaces could be regarded as an opportunity for the development of a region is connected with the characteristics of a real estate product and with potential market analysis. A demand and supply analysis is defined through the supply of spaces in terms of viability. The definition of a Brownfield site is related to the notions of market failures and market constraints (Ferber *et al*, 2006) and (Groenendijk, 2006).

The lack of information about areas to be redeveloped is related to “layers of risk” to the structural specification of Brownfield and would be the main constraint is how it can be financially sustainable of redevelopment. At this point it must be specifically considered the category of benefit that splits in its turn the social and economic benefits (De Sousa, 2000) from the direct financial benefits for specific actors: in the first case the intangible factors affect the evaluation of viability of a site and in the second case the requirements of business plans are strictly connected to the time to come to fruition of the renewed asset.

Another layer of risk is featured by restrictions at the urban planning level, resulting in a set of constraints and limitation for the end use of the redeveloped area. The end usage of the area can be influenced by the typical features of the area of the building objects into the area, and of the characteristics of the neighborhood (Ferber *et al*, 2006). Accessibility, location, and physical condition are fundamental categories of the Brownfield areas to be redeveloped, additionally the different level of

possible contamination that renders it impossible to attain a standardization of reclamation and development costs for sites. Necessary information retrieval and data mining are to be considered as a cost burden due to activities connected to the project management of the renewal of the site. Preliminary studies incorporate costs, which in fact tend to increase in case of deficient information concerning the history of the site or connected deficient poor due diligence of the site. Here, ICT and Urban and Regional Public Databases would facilitate data processing and knowledge management.

### 3.1 Role of ICT and database information for reducing investment risk

Territorial data in Regione Lombardia are controlled and managed thru a GIS-based data-base. Analysis of the databases of Regione Lombardia reveals differences of needs and interests respectively among different categories of stakeholder (Celani, Ciaramella 2014); which is relevant to understand the interest function of different player into renewal of brownfield areas or regional planning. Table 1 represents stakeholders involved in the process of management of idle or abandoned areas.

Since the 1980s the “Kano Model” has been used in the manufacturing industry in order to enhance product development and customer satisfaction (Kano *et al.*, 1984). The Kano Model is further developed to three levels of requirements, which influence customer satisfaction; (1) “Must-be requirements”, (2) “One-dimensional requirements”, and (3) “Attractive requirements” (Suerwein *et al.* (1996). The categories of requirements can be considered as a scale from very basic level (1), just above dissatisfaction up to the highest degree of satisfaction, “the delight customers” (3).

*Table 1. Basic Structure of Financial Interests and Needs among Stakeholders and Governments of Different Levels. (elaboration by authors)*

	<i>Private stakeholder</i>	<i>National Government and national agencies</i>	<i>Regional Government</i>	<i>Local (municipality)</i>
<i>Financial Interest</i>	<i>Assessment and valorization of the areas (cash-flow)</i>	<i>Attraction of Investments</i>	<i>Management and control Polluted areas</i>	<i>Taxation of the underutilized areas</i>
<i>Information needs</i>	<i>Urbanistic development index, distance from infrastructures (transport, energy, IT), availability of resources</i>	<i>Societal development: Demography Industry, Political Targets, Infrastructure (connection larger networks)</i>	<i>Start-up investment, Growth firms and networks of growth firms,</i>	<i>Square meters of an area, ownership, energy, water supply</i>
<i>Database Information needs</i>	<i>Capability to support new actors on market, Creation of supply and demand</i>	<i>Regional databases are not interconnected under a National one</i>	<i>Regional database georeferenced (available)</i>	<i>Non-fully integrated databases, different for any municipality</i>

Using the Kano model for assessing the needs of the potential customer of a product and a service has widely been considered to be an attractive solution to identify attributes as key drivers to success for

customers' satisfaction (Mikulic, 2007). In Mikulic's review it cannot be found any application in the field of Urban Renewal and attractiveness of the vacancies in terms of quality elements. However identification of quality elements for the potential investor would probably reduce the risk of vacancy, reducing the market failures risk. Considering Territorial marketing as a branch of marketing discipline (Bagautdinova *et al.* 2012) with specific features due to various location externalities, conclude us to regard the potential customer of a regional areas as a potential customer of a common good. Bagautdinova *et al.* (2012) regard the localization decisions of firms relates to the effect of globalization, which in its turn is related to (1) market challenges of international sales, (2) the changed space-time relationship in modern economy and (3) the distribution of migrants flows.

The specific needs of Companies; Regional and Urban strategies can be identified and ultimately coordinated when equilibrium between demand and supply is met; e.g. issues of the demand of spaces (not only physical) and offer of spaces (areas in the urban and regional areas), the general interest etc.

In order to create high quality urban structures that would match complexity of needs, of the "delight customers", tools from Total Quality Management (TQM) such as the House of Quality (Hauser and Clausing, 1988) would be worth applying in urban planning because such tools are developed to optimise multiple variables.

By aspiring to satisfy the customers' needs, an effect would be more competitive regional and urban areas as well as more competitive company that is located with business in the area. A potential use of the Kano Model for territorial and urban development and more in detail, in order to mitigate market failures in idle and abandoned areas re-use and allocation is connected with the idea of functionalization. Kano model represents a sophisticated tool to assess customer's needs, to draw functional requirements, to develop new concepts as a part of forecasting procedures and continuous strategy work. Total Quality Management tools in general have its origin and used in manufacturing sector, which is historically more dynamic and positive to undertake change and innovation than the construction industry. The Kano model is a primarily customer-oriented tool where market failures in the brownfield areas are often connected with a lack of development of a strategy to assess the needs of the market. The needs of innovative industries are often hidden or difficult to be standardized because of their complexity. The identification of customer requirements is a part of the theory development and it is proposed a construction guide for a Kano-based questionnaire in order to develop a tool useful to meet Kano's theory of classification of needs with survey techniques. The use of the method Suerwein *et al.* (1996), according to Kano's theory, and the following implementation for mitigating market failures in abandoned and idle industrial areas re-use is the possible way to understand and assess potential market needs and requirements for vacant space.

#### **4. Vacant space; conceptualisation**

The walls of buildings and physical boundaries are rarely coherent with the organisational activities and the multitude of current spatial needs of urban features like living and working. For example, the needs the organisational dynamics of activities growth firms could ideally expand its activities if vacant space is adjacent to the core activities (Ciaramella and Dettwiler, 2011). Areas with vacant space offer thereby a support to the dynamics of firms that have to expand their surfaces.

Vacant space of buildings has their roots in new constructions due to speculation and forecasted occupancy, as well as vacant space of older building that of various reasons have been abandoned. Some

urban and suburban areas are (1) entirely vacant whereas (2) other areas are characterised by scattered occupancy (Table 2). The former situation (1) gives higher freedom for developers and stakeholders to refurbish and plan new areas; existing building of e.g. historical value can be refurbished and other building are demolished to give place for new infrastructure and construction.

The latter situation (2) seems however to be more complicated: the users of scattered occupancy can consist of dwelling as well of private or public activity; such complexity can be described in multiple interrelated dimensions: economics, sociology, governance and more. Users and inhabitants within scattered areas often have lower occupancy costs compared to dense urban areas. Process and discussion for revitalisation, refurbishment and changes implies an increase of costs, which implies among others a threat of being able to stay due to economic reasons. Social structures are as well subject to change and risk to disappear due to new changes. Experiments with methodologies of local democracy and collective design with work groups as an influencing factor in the planning process has been made since four decades however standardised to a minor extent.

*Table 2. Differences between high spatial vacancy and partially vacant areas. (elaboration by authors)*

<i>Characteristics</i>	<i>Area/District Low Spatial Vacancy, partially vacant areas</i>	<i>Area/District High Spatial Vacancy, entirely vacant areas</i>
<i>New concepts/design</i>	<i>Low freedom</i>	<i>High freedom, e.g. new sustainable design</i>
<i>Image</i>	<i>Influence both positive and negative from existing building stock</i>	<i>Freedom to create wanted image</i>
<i>Function</i>	<i>Existing infrastructure and service; applicability and adaption issues</i>	<i>Freedom to create new concepts of infrastructure and services</i>
<i>Public investment on infrastructure</i>	<i>Dependence on current status; re-investment</i>	<i>Entire new infrastructure, Governmental involvement</i>
<i>Social structure</i>	<i>Mixture of current and new users</i>	<i>New users</i>
<i>Buildings</i>	<i>Existing: refurbishment, friction to refurbish, new construction (e.g. in-fill projects). Mixed use of buildings</i>	<i>Demolition, New construction Refurbishment, Cultural Heritage (Degree of permission to refurbish)</i>
<i>Services (FM)</i>	<i>Divided with current occupiers, Economies of scope</i>	<i>Larger contracts, Economies of scale</i>
<i>TQM</i>	<i>Economies of scope</i>	<i>Economies of scale</i>
<i>ICT</i>	<i>Economies of scope</i>	<i>Economies of scale</i>

The strategic methodologies within manufacturing industry seem to be more advanced than within construction sector; the recent decades most products of manufacturing industries (e.g. textile, furniture, IT-hardware) has succeeded to lower the price for their products due to outsourcing, economies of scale,



free competitive market etc..., the construction sector production has contrarily increased. Reducing building cost has become a governmental topic for promotion where construction industry is encouraged to learn from manufacturing industry in order to attain efficiencies. In the research of Facilities and corporate real estate management, a main issue is in fact the identification of needs among end-users and stakeholders. Therefore it would be appropriate to connect specific needs to specific space and land (Figure 2).

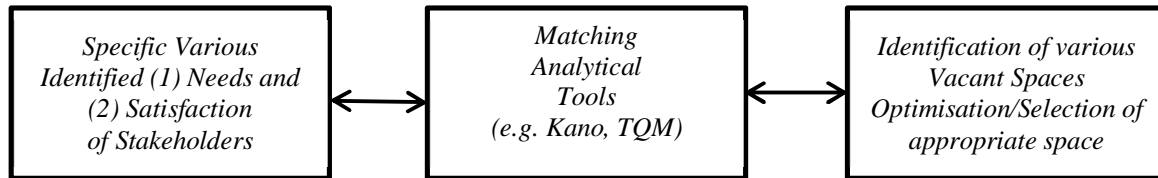


Figure 2: Matching of tools as means that connect identified spaces with identified needs.

Areas with vacant space that have nearness to city cores can be regarded as a reserve for expansion and urban development with first class image and profitability. Example of this are abandoned Wharfs plants or airports of large cities where substantial areas have been successfully transformed into residential areas and activity for the tertiary sector. The European Union conjoint with CABERNET ([www.cabernet.org.uk](http://www.cabernet.org.uk)) has categorized idle land into three categories (CABERNET ‘ABC Model’ of Brownfield Land Commercial Viability). A first approach to classify vacant space is would be the application of these categories and the concepts of Table 2 incorporates the idea of degree of vacancy. Table 3 renders a structure of basic nine categories based on the Kano Model and the ABC-Model subdivided into three main building categories.

Once identified areas enable preparation of strategic facilities management, e.g. bundling of service contracts. Circumstances of entirely vacant areas or scattered occupancy as we have seen in Table 2 give certainly implications on the notion of Table 3, like the extent of service deliveries, economics of scale etc.

Table 3. Basic structure that combines Building categories with ABC Model and areas requirements reading through Kano Model.

<i>Building category /Vacant space category</i>	<i>Manufacturing</i>	<i>Tertiary sector</i>	<i>Residential</i>
<i>A. Commercially viable Sites (Self developing sites) “Attractive requirements”</i>	<i>1.Minor surfaces/workshops in dense urban areas. Efficient and sophisticated services and infrastructure</i>	<i>2. Price Competitiveness, Affordable areas, High price office, established firms. New concepts of FM</i>	<i>3. Competitive flats, sustainable solutions, nearness to work and lifestyle facilities like shops, services, gym etc.</i>
<i>B. Marginal Viable sites (Potential development sites) “One-dimensional requirements”,</i>	<i>4. Affordable areas. Basic needs met and contractual guaranteed. Efficient and safe service delivery</i>	<i>5. Start-up areas. Consultancy, offices, incubators, new high tech firms NTBFs (New technology based firms)</i>	<i>6. New lifestyle image, lower price. Young generation with new lifestyle, connection to entrepreneurship</i>

<i>C. Non Viable Sites (Reserve sites)</i> “Must-be requirements”,	<i>7. Expansion areas, connected to 4.</i> Basic service	<i>8. Expansion area. Low tech service firms (cleaning, repair shops etc.)</i>	<i>9. Separated from 7. But not 8. Basic cheap living for e.g. temporary staff</i>
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The identification of specific vacant space that would match specific needs is primarily dependent on current methodologies like ICT, BIM (Building Information Modelling), POE (Post Occupancy Evaluation), Forecasting methodology (e.g. scenario planning) and DSS (Decision Support System). The proposed inclusion of manufacturing strategic tools, like Kano model, should be regarded a contribution to the present complexity of planning tools. We mean that it would be worth to evaluate and further undertake research how manufacturing tools that can be implemented in existing system like BIM.

The logic and mathematical understanding of the problem can be expressed as follows:

$$S_{TOT}=S_{OCC}+\sum S_{VAC}=F(N_{FIN},N_{ECO},N_{SOC},N_{RES}) \quad (1)$$

- $S_{TOT}$ =Total space of limited area (Buildings, Lands, Infrastructure) of e.g. an industrial plant.
- $S_{OCC}$ =Present occupied space of an area, to be remained or relocated, or incorporated in future changes.  $S_{OCC}=0$  in total abandoned areas as often is the case with brownfield areas for example.
- $N_{FIN}$ ,  $N_{ECO}$ ,  $N_{SOC}$ ,  $N_{RES}$  are the various identified needs among users and stakeholders in basic parameters that also defines the notion of sustainability of today, namely a balance of financial, ecological and social perspectives.  $N_{RES}$  represents factors that cannot directly be categorised in the three mentioned perspectives.

Continuing the reasoning of Table 3 above, the factor  $\sum S_{VAC}$  of formula (1) would thus be a composition of the various identified vacant spaces consisting of land, infrastructure and buildings. The Kano model expects to connect the vacant spaces to various levels of services and facilities management concepts. The space dynamics between the different categories incorporates as well service activities, which would have a significant role unifying the entire area in order to attain efficiencies and goals. By that reason the mentioned spaces in formula (1) could as well be replaced by a composition of services, which we here name D, thus

$$D_{TOT}=D_{OCC}+\sum D_{VAC}=F(N_{FIN},N_{ECO},N_{SOC},N_{RES}) \quad (2)$$

The idea of formula (2) is as well similar to the thinking within facilities management to regard spaces also as a service *per se*, thus

$$D_{TOT}= S_{TOT} \quad (3)$$

Formula (3) has no operative value but should rather be considered as the idea of supporting space dynamics and incorporate flexibility to future change within the planned area.

## 5. Discussion

There are multiple ways to generate space, underutilized or abandoned; in the industrial and manufacturing sector respectively, the disappearance or relocation of heavy industry; aggressive policies attracts investments from countries, where the cost of labour and where the energy consumption is very

low and which in its turn allows companies to increase their competitiveness. Functional obsolescence of some buildings, which take advantage of phenomena of re-location; but also in the service sector, according to the phenomenon that sociology calls "despatialization of labour" (Beck, 2000). In essence, for different reasons, the use of the space occupied by production activities and tertiary sectors gradually decreases; this implies the need to understand if and how this space can be used for a new lifecycle or whether it is necessary to think about a radical change of the original use. To understand the possible application of space, an appropriate interpretation of data like the qualitative characteristics and data mining of spaces or areas is necessary for further processing to the mentioned Kano model and DSS (Decision Support Systems).

The intrinsic problematics in Facilities Management methodology is the measurement of satisfaction (in order to identify needs) which one can suspect has various ground for biases. For example when users are regularly involved in surveys, workshops, interviews, post-occupancy evaluation (POEs) etc. an habitude to express and define needs, satisfaction and desires has uneven weight and proportions among different categories of users and stakeholders. This is not only a managerial problem but also a democratic and sociological problem. The boundary between "need" and "desire" is furthermore a not explored area and of considerable significance in the briefing process. A layering and categorisation of service concepts based to the Kano Model would favourably contribute to an appropriate identification of needs.

Vacant space might represent a problem but, in some cases, also be regarded as an opportunity: at the urban scale, at the scale of single plot and in the case of individual buildings. At urban scale, vacant space would encourage expansions and developments, giving rise to new functions; at the scale of a single plot, unused space can be a solution for congested areas: the most frequent concerns central or semi-central areas, where productive activities have been developed and after years they see turn their original vocation, the surrounding areas are transformed in residential areas and because of that any expansion of business set up is allowed (in Italy, the city of Milan has many cases of this type). The presence of areas throughout the city, with different sizes, becomes a problem that cannot be managed in an urban perspective, but requires as well the ability to analyse regularly local needs; which enable a retardation of the process of regeneration. At the scale of individual buildings, the free space may constitute a reserve to support any need to grow their business for end users or the possibility of entering new strategic functions.

Another significant theme is the importance to avoid the distortion of the vocation of the territories and to leave traces that make up a real cultural heritage. The physical nature of the land to its original state, but especially the artificial environment transformed and conditioned as it appears, where virtually nothing is excluded and potentially unrelated to technological environment, have become the object of study and conservation projects, transformation, but also of real 'restoration' of objects and places. Objects and places where for decades has operated a transformation of productive type, which has involved technological and human resources, where the traces of the past chase and overlap, creating synergies and contiguity that form the backdrop of our lives must be organized and this should engage the stakeholders in an integrated and comprehensive approach towards the future use of the land. Slow or sudden changes of entire territories, birth and death of small and large urban concentrations, productive areas, factories, industries, deserve systematic analysis to properly address any future project.

The fundamental problem of planning areas vacant space is the multitude of data, different interests and number of persons involved in the process. The ICT technology of today enables data processing and

extracting appropriate information for planning, briefing and decision. The challenge to interweave complex factors is a part of managing processes and changes in manufacturing industry. It is to assume that the skill is more advanced in manufacturing industry because it is applied in daily continuous and standardised process, whereas the development an area of vacant space or brownfield area is a unique project where specific solutions must be tailor-made for the particular area. Planning experience from a developed area can only partially be transferred to another area.

Finally, since we argue that vacant space should be regarded as a valuable expansion resource and as reserve space *per se*, it would be motivated that new planned and refurbished areas of e.g brownfield never should be to 100 % occupied; some parts vacant space should be maintained as support for core activities of present companies, dwellings and organisations. Unsolved is still the partition of financing the vacant space.

## 6. Conclusions

In this paper we have argued to incorporate methods, learnings and ideas from the manufacturing industry into the planning process of idle and vacant areas. By means of primarily the Kano Model a higher accurateness is expected in order to identify various categories of vacant space, that would match varies needs. We argue that a better matching of spaces to various needs must as well be related to future urban structures with new values and attitudes, not only regarding finance and entrepreneurship, but also concerning sustainability, sociology and culture. New constructed or refurbished areas are not only “bricks and mortars” but also a physical space for activities and performance of complex services like FM and social interaction. Such progress within planning process would in fact be harmonized with the ideas of United Nations, where the notion of sustainability is defined through multiple perspectives.

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# Size and Nature of the Auckland Private Rented Sector – Implications for the Spread of Housing Options

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## Abstract

Housing scarcity and unaffordability in recent years has been a major concern in New Zealand's major cities, especially in Auckland. The need to accommodate New Zealand's growing population is a concern that is central to government housing policy, with attention having recently been focused on the capacity of the private rental sector to meet a range of housing needs. The objective of this research was to investigate the size and nature of the private rental housing sector in the Auckland region and to examine how the sector contributes to the spread of housing options in the region. Through the analysis of the existing data from five consecutive censuses, the research findings present a detailed analysis of the Auckland private rented sector, with a particular emphasis on the types of household it accommodates, their location within the region and the main housing typologies. These findings will assist various organisations and public authorities to establish priorities in their housing strategies in a way that best meets the demands of the current market, and also to clarify issues around the efficacy of existing policies relating to private renting.

**Keywords:** Housing, Private Rented Sector, New Zealand, Auckland

# 1. Introduction

Private renting is gradually becoming a reality as home ownership is increasingly difficult to attain in several major cities in New Zealand. The decision to own or rent a home is undoubtedly crucial for every household around the world including New Zealand. In recent years, New Zealand has experienced a substantial increase in the number of migrants in Auckland, which has subsequently led to a housing shortage and drastic increase in house prices, causing further housing pressure for low to medium income households. Many people will have some experience of renting privately during the course of their lives. Private renting offers a multitude of roles in housing biographies across the whole social spectrum, serving as a first port of call for new households, a 'bolt-hole' when housing circumstances change, a stopping-off point as people change jobs and move house, and for many households a long-term home.

The need to accommodate New Zealand's growing population is a concern that is central to government housing policy, with attention having recently been focused on the capacity of the private rental sector to meet a range of housing needs. The Productivity Commission (2012) considers it desirable for the housing market to maximise the options available for quality housing for everyone, regardless of income or tenure choice. As in other countries, disparities exist in the housing market in New Zealand. Sixty-four percent of low and middle income households in New Zealand reside in private rental homes and are likely to suffer from the effects of poor quality housing and unprofessional landlords (New Zealand Institute of Economic Research (NZIER ) 2014). Increasing population and projected growth in the private rental sector is a trend in a number of western countries and is a likely feature in New Zealand's property market. An understanding of the size and nature of the private rental sector is necessary in order to gain an understanding of housing typologies that need to be built, and the changes required to existing dwellings to accommodate these households. Moreover, it is important to understand the New Zealand private rental sector's capacity in order to determine how the sector's growth could be tailored to accommodate the country's rapidly growing urban population, particularly low and middle income households and specifically in Auckland. The key objective of this research is to examine the size and nature of the private rental sector, and the contribution it makes to the spread of housing options. The findings from this research will provide a reflection of Auckland's private rented sector, which is necessary to assist various organisations and public authorities to devise housing strategies and to re-establish their priorities according to the increasing population and housing demand.

## **2. Literature Review**

Housing affordability in New Zealand, particularly in Auckland, has been a topic of growing concern for policy-makers and researchers. There has been debate around: the causes of rapidly rising house prices; the increasing disconnect between income levels, rent increases and house prices; and the degree to which affordability is actually a significant problem. Bassett and Malpass (2013) attribute declining housing affordability to a range of factors, including changes in household size and composition, increased building costs, shifting government rules and local government regulations. The Productivity Commission (2012) in their *Housing Affordability Enquiry* noted a range of potential factors contributing to rising house prices ‘such as land supply restrictions, the problems with achieving scale in new house construction and inefficiencies, costs, and delays in regulatory processes’. They also highlighted concern around affordability for renters, although rents have not increased at the same rate as house prices, and noted ‘that the current approach to social housing in New Zealand will not provide sufficient support for those in need’. Auckland is not alone among large cities worldwide in experiencing affordability problems, as similar trends are available in the USA, where with high amenities, growing populations and physical constraints they have also experienced high rates of housing price growth (Cowan, Burrough et al. 2014). The private rental sector is growing in proportion to the decline of home ownership and the low base of state housing, so increasing numbers of people now rely on rental accommodation. Private rented accommodation as a tenure has long been associated with affordability, due to the sector’s perception of alternative housing for people who cannot afford owner-occupied homes (Bramley 2012). According to Rugg and Rhodes (2008), policy interventions that will change the private rented sector’s perception as a housing option that sits behind the preferred tenures of owner-occupation and social renting are important. The private rented sector has the capacity to deliver new and affordable property supply, if backed up with adequate planning and policy interventions (Rugg and Rhodes 2008).

## **3. The Private Rented Sector: A New Zealand Perspective**

New Zealand’s rental market is comprised of the private rented market, social housing and mixed rental housing. In the private market, the landlord is a private person and tenants pay market rent with no government assistance. Also the quality of homes may be actively managed (and achieve a very high standard, e.g. new apartments built to code) or not managed at all (with the resultant range of quality down to the very poorest accommodation options). In the social housing sector, the landlord is the local government and tenants are recognised as vulnerable and are supported by a range of government agencies – the house quality is managed by landlord asset management. In the mixed rental category, the landlord is a private person and the tenants pay market rent but



receive government accommodation assistance or support to supplement rent. Rental housing markets vary across the country, with Auckland under considerable pressure. The percentage of households renting privately in Auckland has increased, while the percentage renting from social housing or a local authority has reduced significantly. 76.9% of households in Auckland rented privately and 19.0% rented from the local authority. Elsewhere in New Zealand the trend is the same, with those renting privately making up 84.9% of renting households in 2013, compared with 79.0% in 2001 (Statistics New Zealand 2013).

The rental housing market is impacted by challenges faced by the housing market: affordability and supply. Generally, New Zealand has seen a significant decline in housing affordability as real house prices are accelerating faster than income. This decline in affordability make it harder for the renters who were hoping to rent only for a short time while saving to buy a home (Cowan, Burrough et al. 2014). Some parts of New Zealand have a shortage of homes as new house construction is below demand from population growth, household size change and migration (Cowan, Burrough et al. 2014). Demand for new housing is estimated to rise by more than 20,000 households per year and most of that growth is predicted for the Auckland region. An NZIER (2014) public discussion paper notes New Zealand has restrictive rental conditions when compared internationally. Tenure arrangements such as typical lease term, notice period for landlord, reasons a lease can be terminated, pet ownership and minor alterations (putting up pictures, painting, laying carpet) are more restrictive than in other countries such as Germany, France, The Netherlands and the UK. Such restrictive rental conditions makes rental housing a poor substitute for home ownership (NZIER, 2014). The insecurity of tenure is a clear barrier for tenants who might want to improve the condition of their rental home; it undermines renters approaching landlords to ask for repairs and maintenance, let alone performance upgrades (e.g. extractor fans, insulation) (Cowan, Burrough et al. 2014).

The private rental market might need to make significant adjustments in order to contribute to the demand growth in the face of not only reduced home ownership propensities, but also reduced government involvement in the provision of social housing. Also, the emergence of ever-increasing housing prices focused on the major cities such as Auckland and Christchurch, while some research by the Centre for Housing Research and Statistics New Zealand provides a valuable overview of the rental housing sector, but none of them are designed to offer the freedom of accessing specific information tailored to the private rented sector. An understanding of the current status of the private rented sector in terms of its size and nature is important to reveal multiple ways to approach the housing issues from several directions and provide relief for the overheated market.

## **4. Research Method**

A quantitative research method was adopted in this study. Pre-existing data from New Zealand's last five censuses conducted between the period of 1991 and 2013 sourced from Statistics New Zealand was used in this study. The data was analysed using a filtering and clustering analysis method. It involved filtering out irrelevant data and the division of the collected data into similar household groups. While there were other methods of analysis suited for investigating pre-gathered data, the chosen method was renowned for providing statistically valid results (Pearce 2013). To ensure result accuracy, only the total number of households who have stated their type of tenure was used as a basis of calculating the percentage of the group in each table. The households who have not stated their tenure have been excluded. The problem was that difficulty in data collection from apartment dwellers, which is known as 'no sign of life', negatively, affected the quality of the census data in 2006 and 2013.

## **5. Results: Size and Nature of Auckland Private Rented Sector**

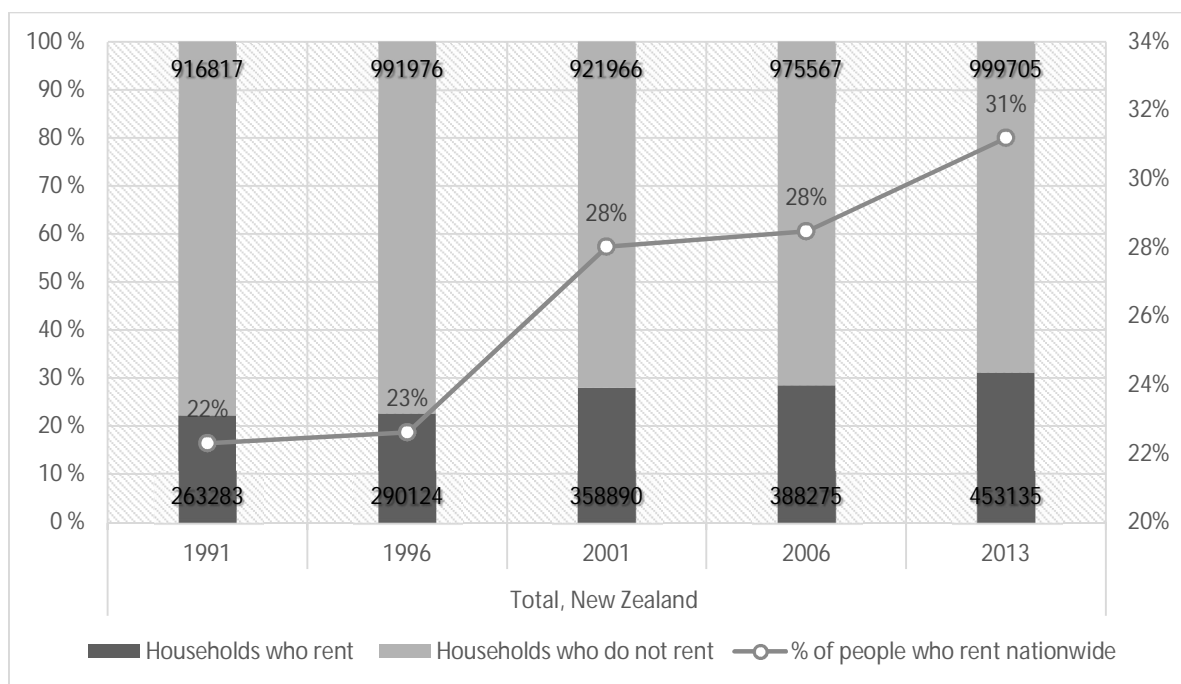
This paper reports a part of the findings of an on-going research study at Massey University undertaken to determine the composition of the private rented sector and its implications for the spread of housing options in Auckland. This section provides answers to the research question posed in this study, through the analysis of existing data obtained from New Zealand's last five censuses available via Statistics New Zealand. Tables and charts are created and simplified where necessary to make the data easy to understand.

### **5.1 Tenure trends in the private rented sector across New Zealand**

The private rented sector is currently thriving in New Zealand. The research results showed that between 1991 and 2013 the total number of renting households across the country steadily increased at an average increase rate of 0.4% per annum to reach approximately one-third of the total number of households in New Zealand. The percentage of renting households across the country steadily increased over the 22-year period, with a tendency towards the continual growth of the private rented sector. The changing size of the private rented sector over the last two decades compared to households not renting (owner-occupied and social housing) is illustrated in

Figure 1. This continual increase in the growth of the private rented sector may be attributed to several factors that include shortage of housing supply and increasing unaffordability. Moreover, households may choose to rent because renting offers flexibility and it provides access to housing and locational services that would be costly. While for some renting is the tenure of choice, for many it may reflect an inability to access home ownership.

*Figure 1. Percentage increase and proportion of total households who rent vs do not rent in New Zealand between 1991 and 2013*



## 5.2 Regional distribution of renting households

There are considerable regional variations in both the size of the private rented sector and the extent of growth experienced across the regions in New Zealand. The renting population was the highest in Auckland out of all the regions of New Zealand (10.6%), followed by the Canterbury and Wellington regions (3.7%), and Waikato (3.1%), and the rest of the regions have an evenly distributed number of households (see Table 1 below). Auckland's significance at a national scale is illustrated by comparing its number of renting households with other major cities, indicating that approximately one-third of all renters in the country are located in this region.

*Table 1. Distribution of renting households around New Zealand's major cities*

Area	2013
------	------

	Distribution of renting households		
	% against total number of all households nationwide	% against total number of renting households nationwide	Numbers
Otago	1.4%	4.6%	20,877
Manawatu-Wanganui	1.7%	5.4%	24,624
Bay of Plenty	2.0%	6.5%	29,280
Waikato	3.1%	9.8%	44,589
Wellington	3.7%	11.9%	53,931
Canterbury	3.7%	11.9%	54,084
<u>Auckland</u>	<b>10.6%</b>	<b>34.1%</b>	<b>154,347</b>
Others	4.9%	15.8%	71,403
Total households renting	31.2%	100.0%	453,135
Source: Statistics New Zealand (2015)			

The regional differences in the private rented sector across New Zealand could be related to the strength of the economy and the wider housing market in Auckland (Scanlon and Kochan 2011). In areas of relatively high economic performance such as Auckland, Wellington and Waikato, growth in the sector has been driven by high house prices, migration, housing supply shortages and high demand, and a relatively high proportion of mobile workers and students. Canterbury economic growth, however, could be attributed to the extent of post-construction activities and job opportunities, as well as the resettling of affected communities after the earthquake swarms in the region since 2010. By contrast, in areas of lower economic performance, growth is more often driven by a lack of supply of (and therefore access to) social housing. Besides, the number of households who rent in Auckland rose from 32% to 35% between 2006 and 2013, with no rise between 2001 and 2006 (see Table 2). This explains the beginning of an era of skyrocketing housing prices and the imbalance of housing supply and demand in Auckland, coupled with migration.

*Table 2. Number of households renting in Auckland vs total number of households in Auckland*

Area	Auckland region		
Year	2001	2006	2013
Tenure of household			
Households who rent	116,694	130,230	154,347
Total households stated	367,395	403,455	437,649
% of households who rent	32%	32%	35%

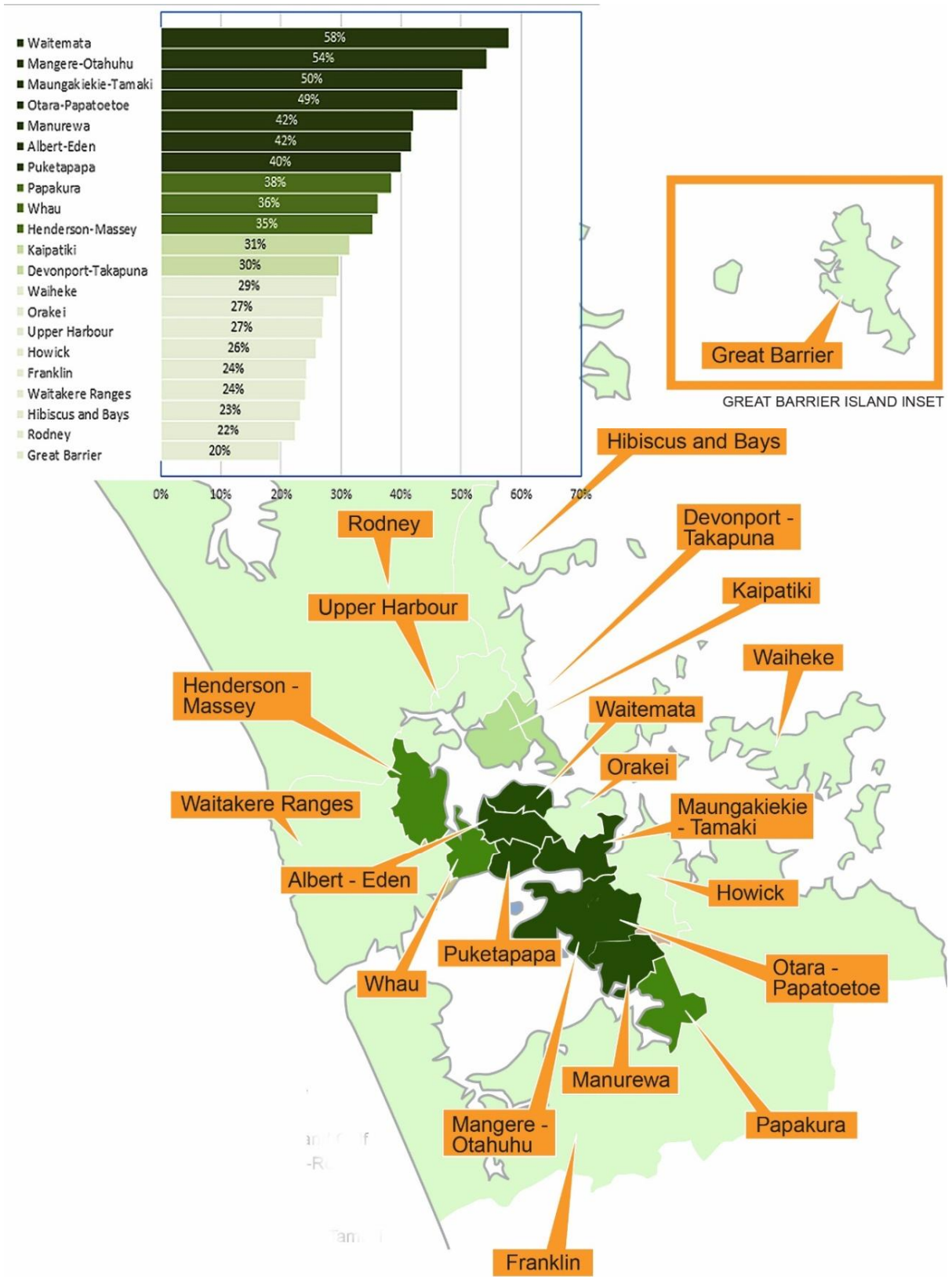
### **5.3 Households who rent**

All 21 local board areas (LBAs) within Auckland, other than Orakei, experienced an increase up to 8.0% in the proportion of renting households between 2001 and 2013. Waitemata and Mangere-Otahuhu LBAs had slightly more numbers of renting households than the households who owned their houses in 2013 and experienced the most rapid growth (6.3%) between 2006 and 2013, along with the Otara-Papatoetoe LBA (5.7%). As illustrated on the distribution map in Figure 2, most of the renting households were located close to housing, work and locational services. Furthermore, households who rented their home were most likely to be one-family households (63.3%) or one-person households (23.5%). These are households that contain a one family nucleus, which can be a couple, a couple with children, or one parent with children. Other people who do not form a family, and who can be related or unrelated to the family, may also be present in the household. One-person households were the second most common, making up 18.4% of renting households in Auckland, while other multi-person households (such as unrelated people flatting together) made up 9.3% of households who rented their home. Most households who rented were doing so from the private rented sector (83.7%), an increase from 81.8% in 2006 and 78.4% in 2001.

### **5.4 Predominant Rental House Typology**

In general, rental housing tended to have fewer bedrooms than housing that was owner-occupied homes. Of households who rented, 29.0% were in a two-bedroom home, compared with 13.8% of households who owned their home or held it in a family trust. Households who rented their home were less likely to be in a four-bedroom home (at 13.4%) than households who owned their home (28%). As illustrated in Table 3, most renting households consist of three-bedroom and two-bedroom dwellings. This is not much different when compared with the national and total Auckland average. In contrast, relatively high numbers of one-bedroom dwellings (41.0%) are located in the Waitemata area where the Auckland's CBD is located.

Figure 2. Percentage of renting households in each LBA in 2013



*Table 3. Renting households by number of bedrooms in Auckland LBAs in 2013*

<b>Number of bedrooms</b>	<b>One bedroom</b>		<b>Two bedrooms</b>		<b>Three bedrooms</b>		<b>Four bedrooms</b>		<b>Five or more bedrooms</b>		<b>Total households stated</b>
Area	No.	%	No.	%	No.	%	No.	%	No.	%	No.
Total New Zealand	54717	13	126171	29	176994	41	58452	13	17895	4	434229
Total Auckland	21168	14	45273	31	55029	37	19362	13	6537	4	147372
Rodney	477	12	1089	27	1548	38	684	17	258	6	4059
Hibiscus and Bays	729	10	1905	27	2859	40	1233	17	372	5	7092
Upper Harbour	453	11	996	23	1506	35	960	22	381	9	4296
Kaipatiki	840	10	2382	29	3603	44	984	12	357	4	8166
Devonport-Takapuna	726	13	2157	38	1899	34	657	12	189	3	5631
Henderson-Massey	708	7	2316	22	5607	53	1593	15	450	4	10671
Waitakere Ranges	492	14	849	24	1626	45	480	13	135	4	3579
Waiheke	189	20	348	36	330	34	81	8	21	2	963
Waitemata	6750	41	6306	38	2280	14	738	5	312	2	16386
Whau	1086	14	2154	28	3243	43	828	11	267	4	7575
Albert-Eden	2493	21	4938	41	2979	25	1182	10	504	4	12096
Puketapapa	690	12	1824	31	2268	39	792	14	279	5	5853
Orakei	1056	15	2688	37	2196	30	999	14	330	5	7269
Maungakiekie-Tamaki	1185	12	4317	42	3633	36	858	8	240	2	10230
Howick	711	7	2481	25	3972	40	2100	21	609	6	9873
Mangere-Otahuhu	687	9	2025	27	2985	40	1239	17	558	7	7494
Otara-Papatoetoe	708	9	2640	33	3519	44	840	10	357	4	8064
Manurewa	369	5	1554	20	4341	55	1230	15	450	6	7947
Papakura	312	6	1191	24	2382	48	858	17	219	4	4962
Franklin	489	10	1095	21	2238	44	1026	20	249	5	5094
Great Barrier	24	32	27	36	21	28	6	8	..		75

## 6. Discussion of Research Results

The private rented sector is currently increasing in absolute size and in terms of the proportion of households it accommodates. Attention has become focused on the capacity of the sector to meet a range of housing needs due to the unaffordability of owner-occupied homes and increasing demand for housing. The private rented sector currently accommodates approximately one-third of Auckland's households, with a projected increase to 42.3% by 2030. Moreover, the number of total rents based on private arrangements is expected to increase because of the government's recent attempt to reform the way state housing is managed, and it is highly likely that the volume

of the private rented sector will remain strong for more years to come, if not increase. Most of the households who are renting outside of the Auckland suburbs tend to live in three-bedroom multi-storey dwellings, whereas households in the CBD were mostly living in one-bedroom unit dwellings. Household types and predominant housing typology location identified through the analysis provided a good indication of where the government and investors can prioritise in their development planning.

The need to accommodate an increasing population in New Zealand is a concern to the government, and attention has been focused on the growth of the private rented sector capacity to help this. However, a lack of framework for providing new housing to the private rented sector may serve as a deterrent to the growth of sector. There is a need for planning regulations with specific targets and objectives that would actively require a certain amount of properties to be let on the rental market in order to meet the predicted demand for housing. For instance, the emergence of younger mobile households and their inability to buy or own homes increases the demand for the spread of universal regulation in the private rented sector across the country. It is possible that where the private rented sector is generating new property, it tends to be in sub-markets where a high-density build is appropriate. The lack of government interference or regulation in housing rental contracts in the private sector is seen by many as challenge that limits the rental market's potential to provide renters with multi-year or even permanent tenancy. When compared to the tenancy contracts of other countries, such as Germany, France, the USA and The Netherlands, New Zealand is one of the most restrictive rental jurisdictions in terms of making minor home alterations, owning pets, termination of lease etc (Gibson 2014). Although the regional-specific correlation between sufficient housing supply and the change in the numbers for rental housing and house ownership is not known, it is certain that enough housing supply will positively contribute to overcoming the current inequality spread in the market. There is a need to identify and map the private rented sector niche markets in order to understand how the market can be defined in terms of demand and supply characteristics, distinctive rental practices, and in some cases specific types of policy interventions that shape the way the market operates.

## **7. Conclusion**

The primary aim of this research was to investigate the structure and size of the Auckland private rented sector and its implications for the spread of housing options. The research results identified the different household types residing in Auckland's private rented sector, their location and predominant building typologies. These results indicated that the growth in the proportion of renting households, coupled with the rapid increase in the cost of rent, signified that housing



ownership in Auckland will become more challenging unless sufficient housing supply comes into action. Regardless of how significant the proportion of renting households becomes, it is crucial that more government intervention or regulatory requirements take place in order to provide sufficient housing options. An example can be creating mandatory minimum requirements for tenancy agreements in order to make renting a more ideal housing option for households.

It is important to note that while the chosen data collection method was best suited for the research topic, the range of data available from Statistics New Zealand and other organisations was not sufficient to carry out the in-depth research that was initially sought. Such a lack of information not only prevented identification of the target population's behaviour over a longer period, but it also discovered what their actual needs might be in terms of getting desirable housing. The availability of detailed information on the target provide opportunity to clarify the issues around the efficacy of existing policy relating to private renting, and the need for further intervention.

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# Payment discipline of public construction clients

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## Abstract

Public sector's payment discipline is said to have a significant impact on the private sector. German construction federations regularly run a comparison of payment practices between public construction clients and private clients amongst their members. The results of this investigation concerning the payment discipline of public construction clients often lead to criticism. Thus the present research project was started to examine independently and representatively the payment discipline of public construction clients. A survey provided the necessary empirical data. Using a standardized questionnaire based on both literature review and expert knowledge, more than 100 public construction clients were interviewed and their answers statistically evaluated. The project results can be summarized in the following categories: Description of payment transactions (partial and final invoices), causes of delayed payments (with different causes found on both sides) and first solution approaches. In conclusion, results show that payment discipline of public construction clients is better than it is said, but still has potential to be optimized.

**Keywords:** public sector, payment discipline, delay, survey, Germany

# **1. Introduction**

The decline in construction volume in Germany since 1995 (minus 17%, minus €45 billion) led to the consolidation of the construction industry; especially in the field of public procurement (minus 28%, minus €10 billion) a continuously declining trend can be observed until today; all other areas (residential, commercial, etc.) show a constant level since the turn of the millennium (Statistisches Bundesamt 2012). In addition, reputation of the public construction clients has suffered on the timely payment of construction services provided (BWI-Bau 2008). In Germany, the payment periods for partial and final invoices are defined in the VOB Part B §16 (DIN 2010). Delays in the payment of already delivered goods and services usually cause additional costs in the form of interest, and these costs are to be reimbursed by those causing the delay. As a result, public sector's payment discipline has a significant impact on the private sector, as Checherita-Westphal et al. (2016) and Flynn et al. (2014) point out.

Surveys carried out by a private construction federation amongst its members (BWI-Bau 2008) are inherently a subjective representation of the situation. In order to understand the real extent and the causes of delays in payment by public construction clients, an independent and representative survey was necessary.

The research project was to investigate the allegations on the part of private construction federations with respect to the payment behavior of public construction clients. This included the identification of payment transactions with non-adherence to the agreed deadlines, finding the cause of the delays in payment and – in the end – the development of solutions or "remedies".

# **2. Research method**

A questionnaire was developed based on literature review and in cooperation with experts using guided workshops. In addition to the reasons for delays in payments, the questionnaire also asked for recommendations on how these delays can be reduced in the future.

Parallel to the preparation of questionnaires, contacts for the interviews were randomly selected out of the population, in our case the public construction clients in Germany. The conduction of the survey followed a uniform pattern: the interviewees received a web link for the online-questionnaire and were additionally introduced to the questionnaire by telephone.

The analysis of the survey results was carried out by electronic means. After the quantification of the payment delay, influence factors responsible for the delay were identified by comparing the average and median values (descriptive statistics). And in the end, first solutions to improve the current situation have been compiled.

### 3. Data

#### 3.1 Population and selection of sample

The objective of the research project was to investigate the payment behavior of public construction clients on a representative basis and on all administrative levels. Consequently, the population of the survey were the public construction clients of Germany. The representativeness of the sample was ensured by a nonspecific and random selection of the sample.

*Table 1: Comparison of population and sample: federal states*

	Population		Sample		Deviation
	Quantity	Portion	Quantity	Portion	
01 Schleswig-Holstein	1,299	8%	36	8%	0%
02 Hamburg	4	0%	-	0%	0%
03 Lower Saxony	1,520	9%	42	9%	0%
04 Bremen	7	0%	-	0%	0%
05 Northrhine-Westphalia	850	5%	28	6%	1%
06 Hesse	890	5%	24	5%	0%
07 Rhineland Palatinate	2,556	16%	76	17%	1%
08 Baden-Württemberg	1,626	10%	55	12%	2%
09 Bavaria	3,629	22%	91	20%	-2%
10 Saarland	111	1%	-	0%	-1%
11 Berlin	4	0%	-	0%	0%
12 Brandenburg	638	4%	13	3%	-1%
13 Mecklenburg Western Pomerania	909	6%	25	6%	0%
14 Saxony	772	5%	26	6%	1%
15 Saxony-Anhalt	362	2%	8	2%	0%
16 Thuringia	1,132	7%	26	6%	-1%
TOTAL	16,309	100%	450	100%	0%

*Table 2: Comparison of population and sample: administrative levels*

	Population		Sample		Deviation
	Quantity	Portion	Quantity	Portion	
Federal state	16	0.1%	0	0.0%	-0.1%
Region	29	0.2%	0	0.0%	-0.2%
„Region“ (only in Baden-Württemberg)	12	0.1%	0	0.0%	-0.1%
District	402	2.5%	4	0.9%	-1.6%
Associated communities	4,581	28.1%	127	28.2%	0.1%
Community	11,269	69.1%	319	70.9%	1.8%
TOTAL	16,309	100%	450	100%	0.0%

## 3.2 Description of data base

### 3.2.1 Public construction clients

The data base was obtained by surveys. 450 people (the sample) were contacted by letter and by phone, which led to a return of  $N = 103$  or a return rate of about 23%. The survey results show predominantly "communal projects (city, less than 100,000 people)" as public construction clients (see Figure 1); this reflects the population.

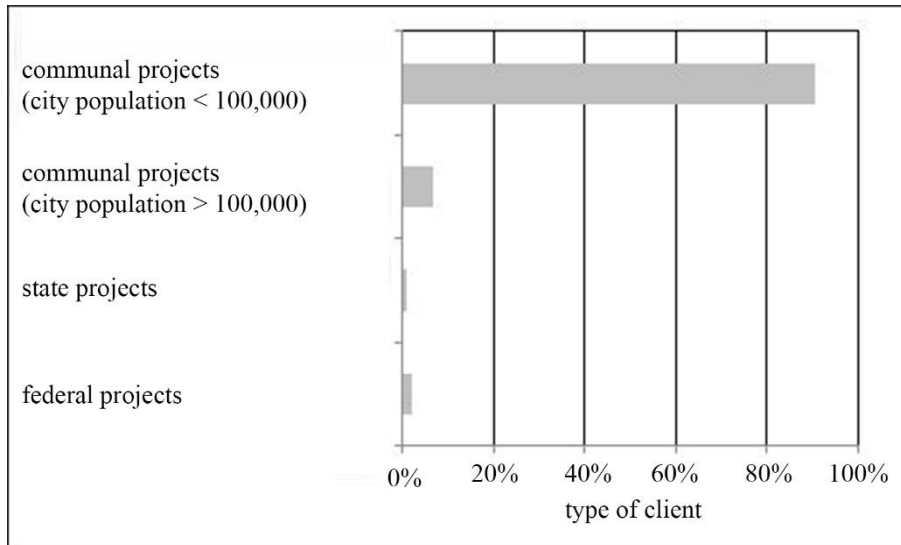


Figure 1: public construction clients per administrative level ( $N = 104$ , multiple answers possible)

Another characteristic of the sample was the question of the "specialized auditor". At only about 30% of the responding public construction clients, inspection took place by internal accounting.

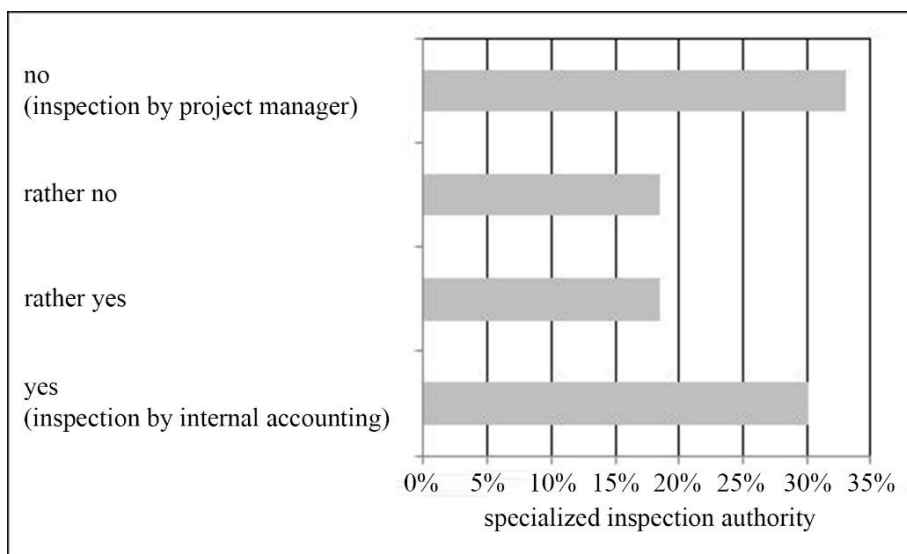


Figure 2: Specialized auditor ( $N = 103$ )

When looking at the distribution of project types, the sample shows a concentration of building and traffic construction projects. Moreover, it became clear that only two projects per year and per project type (building or traffic construction) were handled per public construction client (see Figure 3).

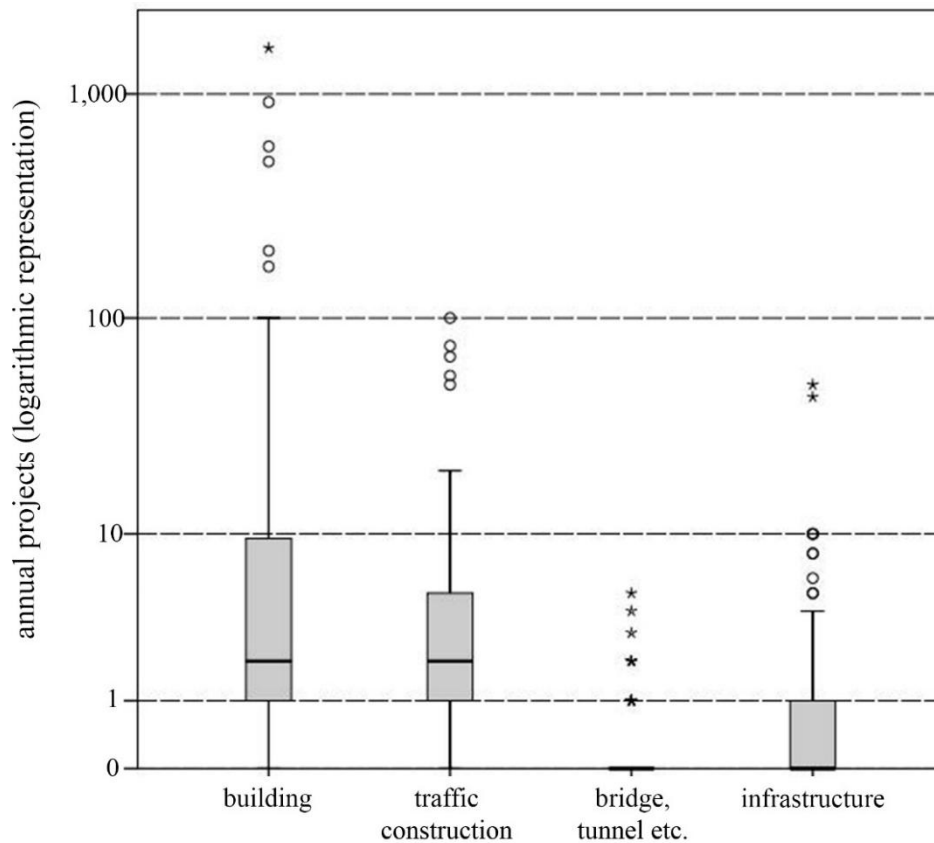


Figure 3: Number of annual projects per project type (logarithmic representation)

Another aspect of the sample is the ratio of 1 project with new building construction compared to 5 projects with or in existing building construction (extension, alteration, improvement, repair and maintenance). The size of the projects was approximately equally distributed on projects up to 10,000 € with a median of 20%, projects from 10,000 to 100,000 € with a median of 30% and projects from 100,000 to 2,000,000 € with a median of 20%. Projects amounting to more than € 2 million were barely represented in the sample, which is plausible for the observed population.

### 3.2.2 Invoices

The examined invoices can be differentiated between type of the order and type of invoice. Type of the order has been distinguished in the survey between the main order and supplementary orders, with 95% (median) on the main order. The invoices due to a supplementary order were generally of minor importance. The type of invoice was distinguished between partial and final invoices. The amount of partial invoices was approximately twice the amount of final invoices, the surveyed public construction clients indicated that they have worked on average on 60 partial and on 30 final invoices per year.

## 4. Results

### 4.1 Auditability of invoices

In Germany, there is a fundamental difference between partial and final invoices when it comes to their different payment periods allowed in accordance with VOB 2009 (Ingenstau 2010). In addition, it should be noted that this period only starts when the invoice is auditable; this date is not necessarily the date of the invoice or the date of delivery of the invoice. The survey results show that 5% (median) of the partial and final invoices were not auditable, while significant variations can be observed. The reasons for non-auditability of invoices based on the survey are displayed in Figure 4. It turns out that especially “error-containing documentation” repeatedly represents a reason for non-auditability.

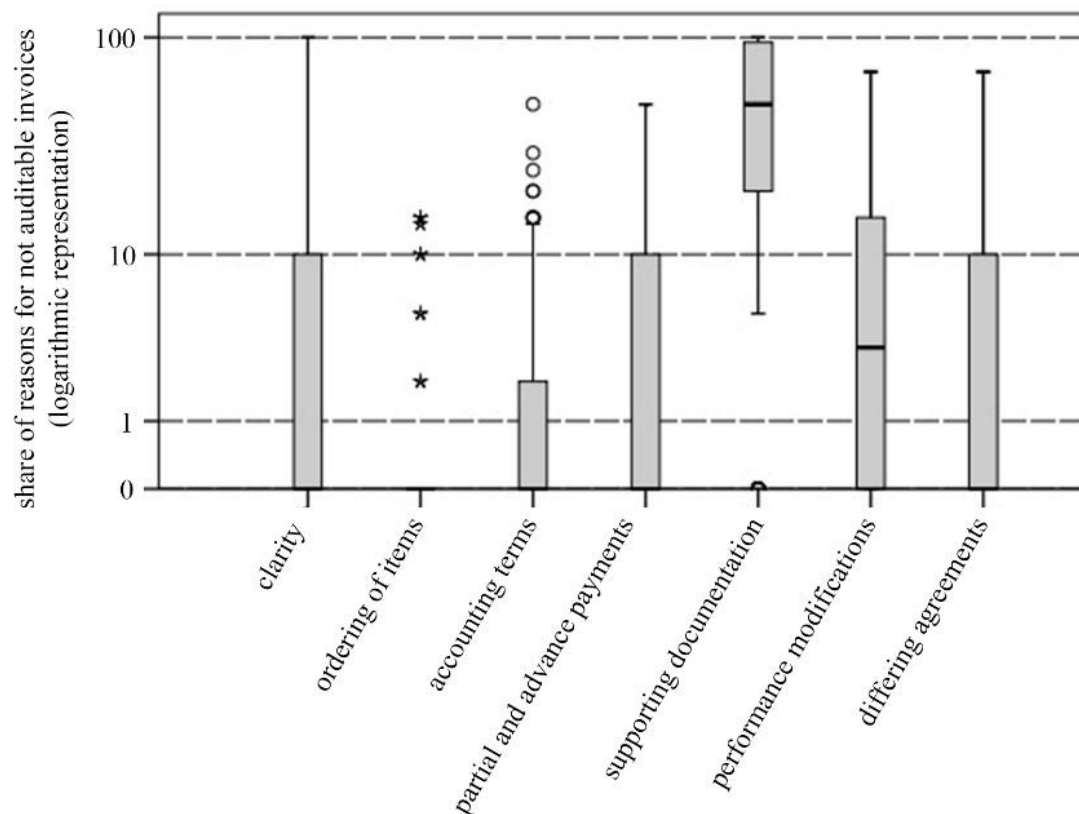


Figure 4: Percentage of reasons for not auditable invoices (logarithmic representation)



## 4.2 Payment behaviour in case of auditable partial invoices

With regard to the auditable partial invoices, the survey results show that according to the public construction clients, a median of 96% of the invoices were paid on time. The distribution is shown in Figure 5. In two cases, public construction clients stated that they paid the invoices on time in 50 % and 60% of cases.

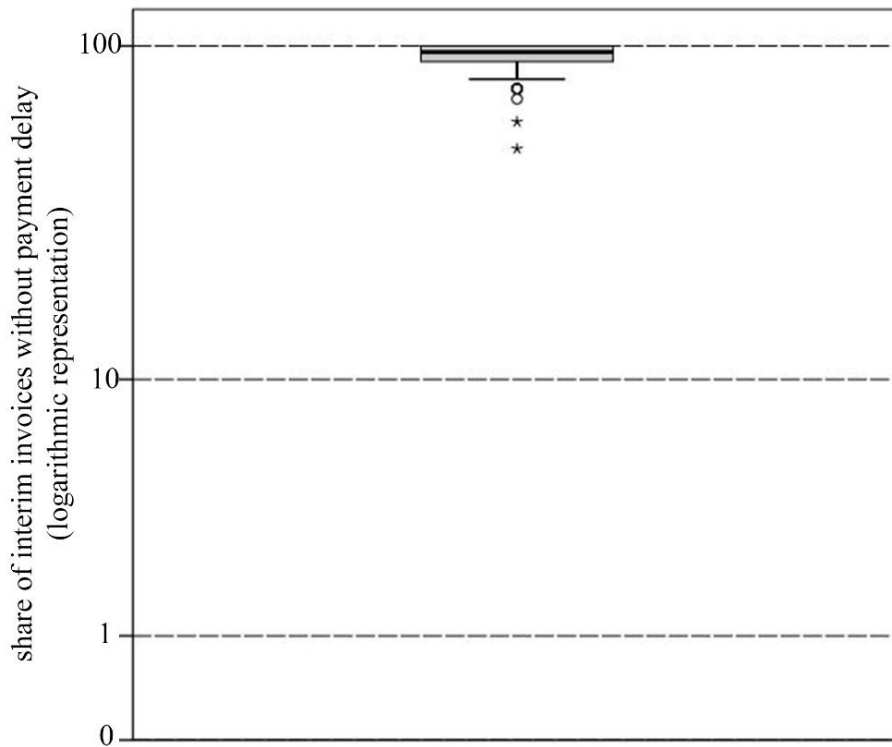


Figure 5: Percentage of partial invoices without payment delay (logarithmic representation)

This result is confirmed by the control question on the percentage of late payments with more than 18 days in accordance with VOB 2009; answers provide a median of 4%, which is the difference to the above 96%.

In addition to the proportion of the partial invoices paid within time or with late payments, the survey results also provide information on the extent of late payments. The survey distinguishes between the delay time and the average invoice amount. For the auditable partial invoices with late payments the following picture emerges: The delay time is 5 days (median) after the end of VOB period of 18 working days (lower and upper quartile at 5 and 10 days). The average invoice amount (median) is 10,000 € (lower and upper quartile at 5,000 € and 15,000 €). It should be noted that this is valid only for auditable partial invoices with payment delays. The partial invoices without payment delays are not included in the evaluation.

### 4.3 Payment behavior in case of auditable final invoices

Similar to the partial invoices, the auditable final invoices show that a large share of the invoices is handled without late payments. According to the public construction clients, they are paid on time with a median of 100% according to VOB (2009) with a given a period of 2 months. Only the lower quartile shows that 95% of the auditable final invoices are paid in due time (see Figure 6). In three cases, public construction clients stated that they paid the invoices on time only in 30, 40 or 50% of cases.

This result is confirmed by the control question on the percentage of late payments showing a median of 0% (lower quartile 5%), confirming the difference to the above 100% (lower quartile 95%).

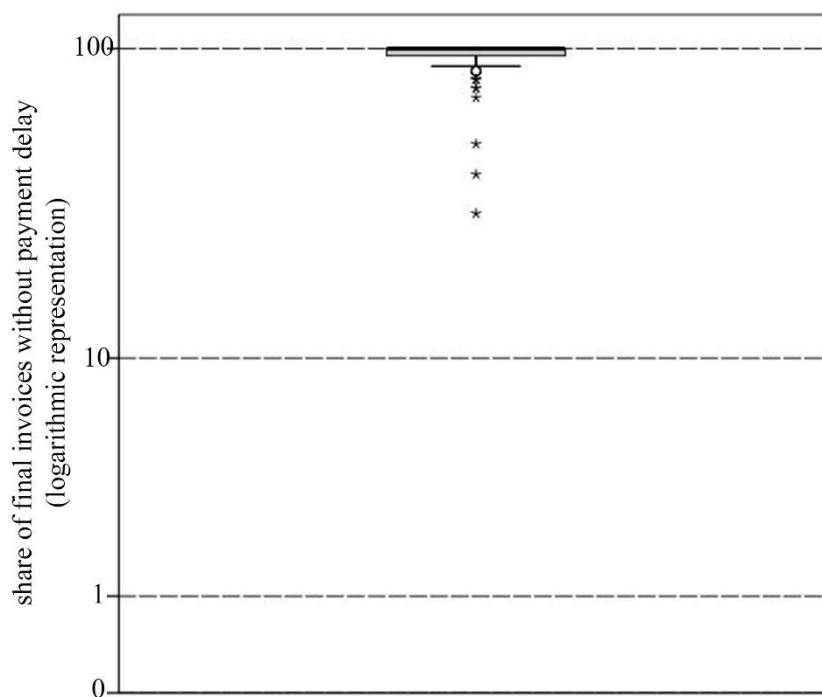


Figure 6: Percentage of final invoices without payment delay (logarithmic representation)

In addition to the proportion of the final invoices paid within time or with late payments, the survey results also provide information on the extent of late payments. Again, the survey differentiates between the delay time and the average invoice amount. For the auditable final invoices with late payments the following picture emerges: The delay time is 10 days (median) after the end of VOB period of 2 months (lower and upper quartile at 10 and 15 days). The average invoice amount (median) is 10,000 € (lower and upper quartile at 6,875 and 20,000 €). It should be noted that this is valid only for auditable final invoices with payment delays. The final invoices without payment delays are not included in the evaluation.

## 5. Discussion

### 5.1 Causes for payment delays

In addition to the detection and evaluation of payment transactions, there was another set of questions in the survey of this project, asking for responsible causes for delays in the payment of invoices. The public construction clients who indicated delays in paying the invoices, explained the backgrounds and named the causes, too. The interviewees could choose of a list of possible causes (as well as add their own) and rate each of these causes from their perspective (distribution of 100% on the respective causes). Within this context, the following causes can be described as relevant, with the specified sequence corresponding to the encountered ranking (see Figure 7): audit by external planning office too long (1<sup>st</sup>), increased work load on the part of auditors, vacation / illness of the auditor, incomplete, unsystematic quantity survey (all 2<sup>nd</sup>). It is thus clear that there are causes that can be found on the part of public construction clients, but also on the part of the other project participants. The public construction client has to deal especially with a limited staff capacity, as "increased workload of invoice auditor" and "vacation / illness of invoice auditor" show. With regard to the other project participants should be noted that some causes (e.g. "incomplete, unsystematic quantity survey") are attributable to the author of the invoice, as well as to other planning offices ("audit by external planning office too long"). The additional mentioned causes for late payments mainly points to the so called "Ortsbürgermeister", a non-professional mayor in villages or small towns, in many cases with lack of time, co-workers and/or experience in public construction projects.

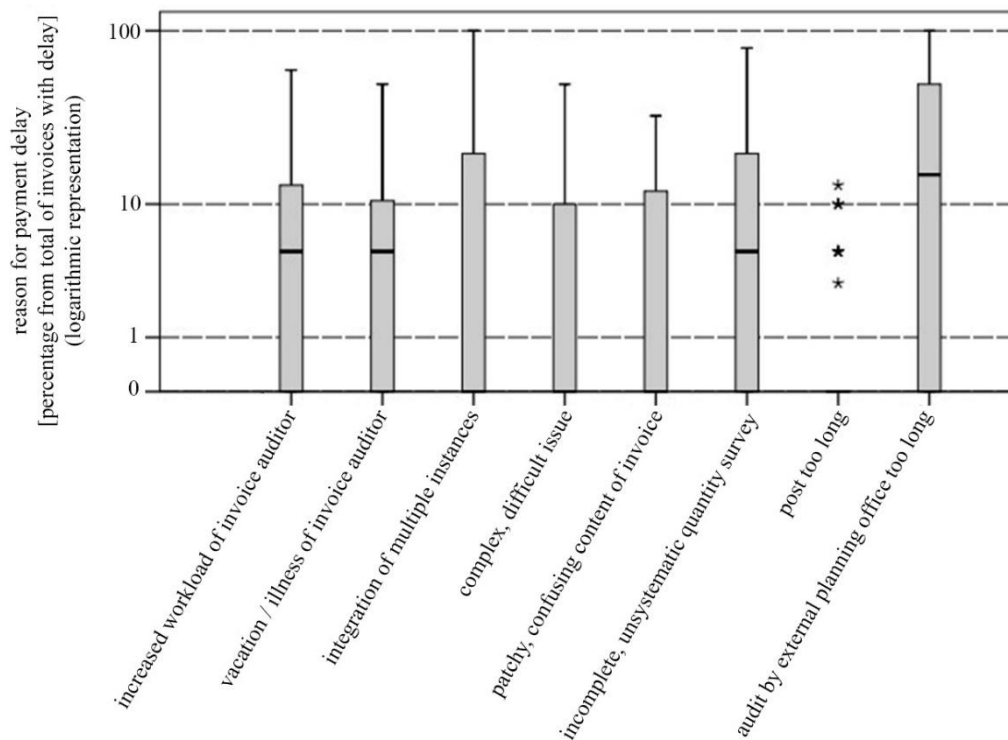


Figure 7: Reasons for late payments (logarithmic representation)

## 5.2 Possible approaches for solutions

Based on the above mentioned reasons for violation of payment deadlines, first guesses can be deduced to tell which solutions might be suitable. The survey also covers this issue, too. In terms of solutions or "remedies" to ensure compliance with the contractually agreed payment terms, the survey shows the following ranking (see Figure 8): early examination of quantity survey (1<sup>st</sup>), increase of internal staffing (2<sup>nd</sup>), clear rules on representation for holidays and disease; in addition, the contractor should be informed about the planned vacation (3<sup>rd</sup>), raising awareness of the public construction client and the laboratory with regard to the problem of late payment eg. by means of events, brochures, etc. (4<sup>th</sup>).

Besides the increase in personnel capacities on the part of public construction clients (2<sup>nd</sup>), there are mainly organizational aspects that seem to offer a solution approach to the problem of late payments in accordance with the survey results (1<sup>st</sup>), (3<sup>rd</sup>) and (4<sup>th</sup>). These organizational aspects are to be found on both sides of the client and the other project partners, and a special focus lies on the "early examination of quantity survey".

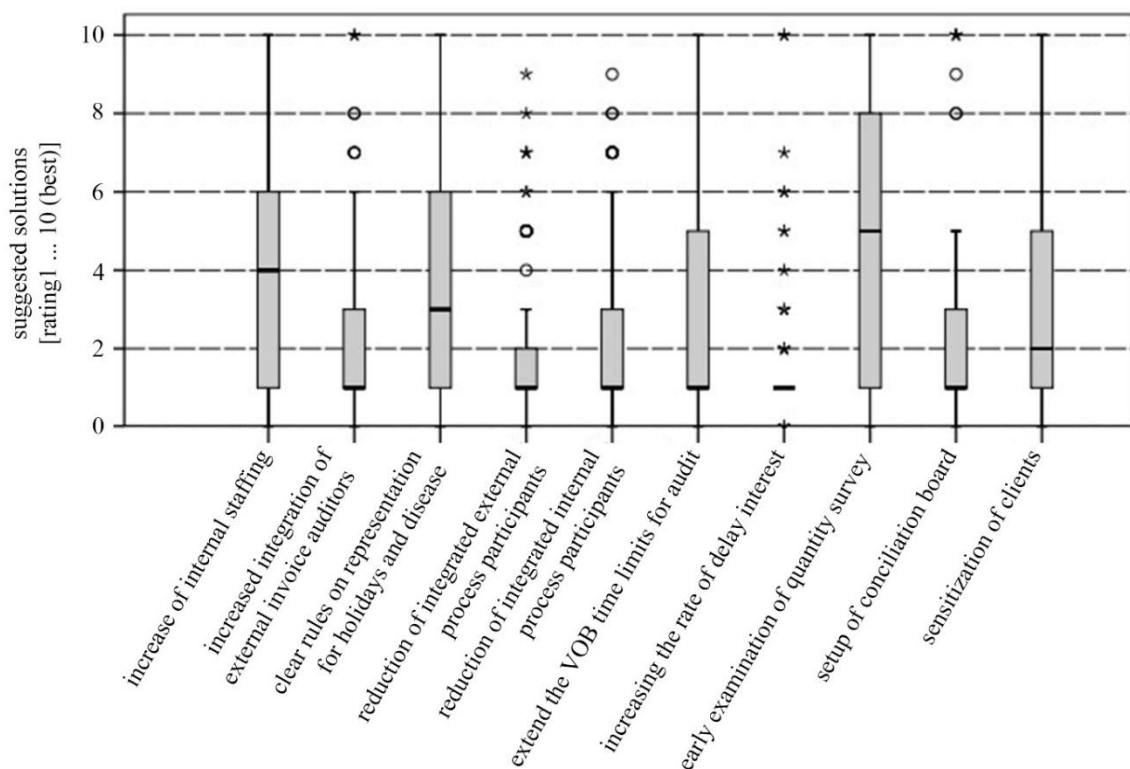


Figure 8: "Where do you see potential to ensure compliance with the payment deadlines?"

## 6. Conclusions

### 6.1 Overview

The results of the research can be summarized by the following points, which in turn represent responses to the initial research questions:

Acquisition and analysis of payment transactions, in particular the sizes and periods between receipt of the auditable invoice and the payment by the public construction client:

Auditable partial invoices show that a median of 96% was paid on time. If it comes to late payments, the delay time was 5 days (median) after the VOB period of 18 working days (lower and upper quartile of 5 and 10 days). The average invoice amount of late payment was 10,000 € (median) (lower and upper quartile of 5,000 € and 15,000 €). Auditable final invoices show that a median of 100% was paid on time. Only in the lower quartile a reduced figure of 95% of the auditable final invoices can be seen. If it comes to late payments, the delay time was 10 days (median) after VOB period of 2 months (lower and upper quartile of 10 and 15 days). The average invoice amount of late payment was 10,000 € (median) (lower and upper quartile of 6,875 € and 20,000 €).

Identification of the causes of delays in payment on the part of the public construction client and on the part of other project participants:

According to the findings of this research project, the causes for late payments lie on the part of the public construction client but also on the part of other project participants. The public construction client has to deal especially with a limited staff capacity, as mentioned by "increased workload on the part of auditors" and "vacation / illness of the auditor". With regard to the project participants, it should be noted that at least two causes are attributable to the author of the invoice ("incomplete, unsystematic quantity survey") and the external planning offices involved in the audit ("control by external planning office too long").

Development and presentation of possible solutions to ensure future compliance with the contractually agreed payment terms:

Besides the increase in personnel capacities on the part of the public construction client (2<sup>nd</sup>), there are mainly organizational aspects that can offer a solution to the problem of late payments in accordance with the survey results (1<sup>st</sup>, 3<sup>rd</sup> and 4<sup>th</sup>). These organizational aspects are to be found on both sides of the client and the other project partners, with a special focus on the early examination of quantity surveys.

Due to the methodological approach - in particular, the random selection of the sample and the unified survey – the present results can be qualified as representative and are transferable to the population (mainly to the administrative levels: "community" and "associated communities").

## 6.2 Outlook

Public sector's payment discipline has a significant impact on the private sector, as Checherita-Westphal et al. (2016) and Flynn et al. (2014) point out. Based on the present study results, the expected continued high relevance of the considered research questions and in addition to the implementation of the outlined "corrective measures" it is recommended to carry out at least one new survey in the medium term to better understand the long term development of the topic (including the initial effects of introduced "corrective actions").

In a new survey, the concept of the actual survey does not necessarily have to be changed fundamentally since it has proved to be viable. However, if the questions should be extended to how the respective results depend on the "type of public construction client", the "state", the "type of invoice auditor" and so on, the sample of the currently about 100 responses would have to be largely extended, too. In any case, the selection of the sample (project construction clients to be interviewed) should be randomly again in order to get a representative picture of the population.

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# Heightened Duties in Integrated Design and Delivery Contracts

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## Abstract

In an archetypal contractual relationship each party is expected to look after its own best interests. Conversely, in a fiducial contractual relationship the fiduciary must act in the best interest of the other party. Integrated design and delivery contracts typically express a relationship of trust and confidence between contractor and owner. These expressions may obligate the contractor with if not strict fiducial duties at least heightened duties. These heightened duties have been characterized variously by U.S. Courts as something more than good faith and fair dealing; as a confidential relationship; or as a fiducial-like relationship.

Heightened duties may arise from a contractual expression of trust and confidence. U.S. Courts may also find that heightened duties are implied in the absence of any contractual expression thereof. Findings of heightened duties by U.S. Courts can be shown to depend more on the relative sophistication of the owner or the owner's agent in circumstances where the contractor can exercise a controlling influence over the owner's interests. And although express words of trust and confidence in a contract may not create heightened duties these expressions do have utility for helping U.S. Courts to find and enforce heightened duties under appropriate circumstances.

Herein proposed is a practical method of assessing the heightened duty expectations of the contractor by graphing a continuum of heightened duties against the level of sophistication of the owner and the ability of the contractor to exert influence.

**Keywords:** Fiduciary relationship, confidential relationship, good faith and fair dealing, integrated design and delivery.

# **1. Introduction**

In an archetypal contractual relationship each party is expected to look after its own best interests. Conversely, in a fiducial contractual relationship the fiduciary must act in the best interest of the other party. A third type of contractual relationship creates confidential duties that lie somewhere in-between the extremes of the archetypal and the fiducial.

To know that a contractual relationship is archetypal, confidential or fiducial is to know what level of duty is expected and how to comport oneself so as not to breach that duty. Unfortunately, construction contracts rarely provide such specificity. Moreover, U.S. courts will find archetypal, confidential or fiducial relationships in the absence of any contractual expressions of those relationships. For now, we define heightened duties as an attention to the interests of the owner that exceeds that of an archetypal relationship without specificity as to whether that obligation rises to the level of confidential or fiducial or how those relationships are created.

The purpose of this paper is to assess the heightened duty expectations of designers and/or builders under integrated design and delivery contracts. It is an analytical paper adopting a classic legal research methodology focused upon primary and secondary legal research sources and designed to provide balanced findings in the form of a memorandum of law.

## **2. Integrated Design and Delivery**

Design-Bid-Build [DBB] is the traditional project delivery methodology in the U.S. DBB has been widely vilified for precipitating highly adversarial project relationships. Such relationships are viewed as a root cause of cost overruns, late delivery, poor quality and owner dissatisfaction. Less in affirmation of this claim and more in a pragmatic acknowledgment that collaborative relationships, management strategies and organizational tactics have revolutionized other industries, the domestic construction industry has been adopting alternative project delivery methodologies. These alternative project delivery methodologies may be loosely categorized into three genres: design-build, construction management and integrated project delivery. Integrated design and delivery, as the phrase is used in this paper, refers to any of those genres or to any hybrid of those genres. The common theme of integrated design and delivery is involvement of a construction contractor early in the design process, typically requiring cost-plus type payment methods.

### **2.1 Design-Bid-Build**

DBB is an established process in the U.S. It is sequential by definition: first the project's design must be completed, next there is a competitive bidding period, then an award, and finally the contractor builds, hence the moniker design-bid-build. Award is usually made to the lowest responsible and responsive bidder. A responsible bidder is one whom meets all business and financial qualifications specified in the bid solicitation (Federal Acquisition Regulation [FAR], § 9.104-2, 1984). A responsive bidder is one who complies with all material requirements of the bid solicitation (FAR, § 14.404-2(d), 1984).



DBB has its shortcomings. One shortcoming arises from the design process. State-of-the-art design solutions arise from two entrées: 1) access to the proprietary designs for equipment, materials and systems provided by manufacturers; and 2) the participation of the licensed specialty subcontractors who install and warrant those manufacturers' products. Designers engaged in the traditional DBB process lack access to both entrées. Thus, DBB tends to generate outmoded design solutions with lower levels of quality, ease of assembly and economy. Outmoded design becomes increasingly more problematic with complex projects.

Another shortcoming is time. Significant opportunity costs are lost while construction waits for the design process to go to 100% completion before the bid process starts and actual construction can begin. Worse, should all of the bids come in over budget, something that occurs all too often, the owner must go back to the designers to have their design revised and made less expensive, and then start all over again with bidding. DBB can be frustratingly time consuming.

Yet another shortcoming arises from the construction process itself. It can be adversarial to excess. This is particularly the case whenever the construction documents are inadequately developed or there is an abundance of performance specifications with indefinite performance criteria. Contractors, labouring under cutthroat, competitive pricing will seize every opportunity for relief through change orders, precipitating highly adversarial project relationships.

## **2.2 Design-Build**

A design-build [DB] contractor, or design-builder, will take responsibility for both design and construction. DB contracts but can be configured with either firm-fixed-pricing or cost-plus pricing. But first, the owner must describe its intended scope of design and construction work and otherwise define its needs. This is accomplished with criteria documents. Typically, an owner, under separate contract with a design firm, develops criteria documents. Once that is accomplished, a two-part bid process begins.

During part one of the process, the owner solicits prequalification information from interested design builders. Responses are used to build a short-list of three to five of the most qualified firms. Typically, firms are not to respond with prices or technical solutions: the owner builds its short-list based solely upon the prequalification responses, such as evidence of prior experience performing the type of design and construction work that is being solicited. Ordinarily, the part one prequalification solicitation, commonly known as a request for qualifications [RFQ], will also define the scope of work of part two, identify both part one and part two evaluation factors, and assert the number of candidates that will be selected for the short-list.

During part two the short-listed candidates are invited to submit two separate competitive proposals in response to a request for proposals [RFP]. One of those proposals is a technical proposal, describing the design builder's technical response to the criteria documents. The other proposal is a cost or price proposal. The owner then picks the best proposal.

DB has its shortcoming. One arises from a hand-off of design control. The owner must rely on their criteria documents to describe their needs with sufficient clarity because apart from the criteria documents the owner will have little, if any, influence over the design. The design builder will design to the criteria documents and respond to the pricing method thereof, not necessarily to direction by the owner.

Another shortcoming arises from reactions to the first shortcoming. An owner wishing to retain more control over design may actually do some of the design and include that in its RFP. Such post-criteria design work is known as bridging. The designer who created the criteria documents is ordinarily retained for bridging. Bridging documents can include conceptual design documents, schematic design documents, design development documents and even some of the construction documents and specifications. Up to 70% of a design has been completed with bridging. But the more bridging, the more a DB project resembles DBB and all of the shortcomings that go with that.

Yet another shortcoming arises from organizational management. DB solicitations have a penchant for one-of-a-kind projects filled with special requirements. The firms that respond tend to be ad hoc teams, assembled from many different firms, each with different specializations, who may have or may not have ever worked together before. DB is a collaborative process between teams with very different interests. For collaboration to prevail over self-interest, working relationships must be founded on trust. Trust, however, is not a commodity; it is an interpersonal phenomenon (Child, Faulkner and Tallman, 2005).

## **2.3 Construction Management**

The construction management [CM] methodology superimposes a CM layer over what would otherwise be a DBB project. Among other things, a construction manager provides preconstruction services. Preconstruction services are services related to design and planning activities such as: an evaluation of the project's program, schedule and budget; preliminary cost estimates; phasing plans; identification of long-lead items for procurement; preparation of bidder's lists; and bid evaluations.

The purpose of the CM project delivery methodology is to provide an owner with independent, third party consultation during design and construction. Early manifestations of the CM project delivery methodology had the construction manager providing preconstruction services during the design phase and administrative services, similar to what an architect or engineer would ordinarily provide in DBB, during the construction phase. This was known as CM-agency [CMa], alluding to a contractual agreement that installed the construction manager as an agent of the owner. The CMa does not guarantee budget or schedule. The owner retains the risk of cost and schedule.

In time, owners began to seek price and performance guarantees from CM firms. General contractors operating as construction managers proved willing, under certain circumstances, to provide these guarantees. A new project delivery methodology evolved, known as CM-at-risk

[CMAR]. This methodology distinctively differs from CMa in that cost and schedule risk is transferred from the owner to the construction manager.

For CMAR, an owner prequalifies construction managers whom have capability to provide both preconstruction services and actual construction. The selected construction manager then provides preconstruction services during the design process using cost-plus-fixed fee pricing. At a point in time when the construction documents are developed to the point of describing the project in sufficient detail, the construction manager provides a price for construction. The pricing method is usually cost-plus-fixed fee with a ceiling price, or cap that may not be exceeded. If this ceiling price, referred to as a guaranteed maximum price [GMP], exceeds the owner's budget, the owner can either order a redesign to budget, at the owner's expense, or stop the work and terminate all contracts. If the project does continue, a construction contract is executed with the construction manager, whose role comes to resemble the traditional role of a general contractor.

CMAR has its shortcomings. The CM layer adds additional costs. Proponents argue correctly that as a general contractor, the construction manager has access to manufacturers and licensed specialty subcontractors and that this results in higher quality, ease of assembly and lower costs. These benefits more than compensate for the additional cost of the CM layer, they argue. But it is often difficult to demonstrate these benefits because CMAR projects tend to be unique projects that do not possess a good baseline for comparison. It is instructive to note that some construction managers will charge little or nothing for preconstruction services, in effect giving them away in exchange for nothing more than the inside track to a construction contract award.

Another shortcoming arises if the construction manager's relationship with the owner during the design process dissolves into self-interest, as the construction manager becomes the general contractor and assumes cost and schedule risk. The owner may become burdened with additional oversight as it tries to administer the construction contract of its construction manager turned general contractor.

Yet another shortcoming relates to the same organizational management concerns that loom over DBB project delivery. At least in DB projects, some designers and builders have a healthy desire to work together. But CMAR is usually conceived as a shotgun marriage between architect/engineer and construction manager/general contractor where the construction manager is brought in, given a mandate over design but no contractual authority thereto. Whenever dysfunction sets in between the design firm or firms and the construction manager or its partners, inferior work products result.

## **2.4 Integrated Project Delivery**

Integrated project delivery is a team-based, lean project delivery methodology (Matthews & Howell, 2005). Its contractual model is typically a multi-party agreement between owner, contractor and design professional. The American Institute of Architects defines this type of integrated project delivery as "...a method of project delivery distinguished by a contractual arrangement among a minimum of owner, constructor and design professional that aligns business

interests of all parties” (AIA National | AIA California Council [AIACC], 2007). The However, the AIACC acknowledges that very few integrated project delivery projects involve such multi-party agreements.<sup>1</sup> (AIA and AIA Minnesota, 2012). Many integrated project delivery projects adapt the collaborative relationships, management strategies and organizational tactics while foregoing the multi-party agreement.

### 3. Heightened Duties

The archetypal construction contract is an agreement in which each party has equal bargaining power. In the past, a party to a contract was expected to look after itself owing no duty of care to the other party. In the twentieth century, jurisprudence in the U.S.A. began to hold contracting parties to the covenant of good faith and fair dealing (American Law Institute & National Conference of Commissioners on Uniform State Laws, 2009, §1-304; Sweet & Schneier, 2013, §17.02D). The United States Restatement (Second) of Contracts defines good faith, as “..faithfulness to an agreed common purpose and consistency with the justified expectations of the other party [and excluding] a variety of types of conduct characterised as involving ‘bad faith’ because they violate community standard of decency, fairness or reasonableness.” (American Law Institute, 1987, §205). For the courts to find a breach of an implied duty of good faith in an archetypal construction contract the aggrieved party would have to show actual fraud.

A different type of relationship arises in a construction contract where there is a disparity of power and control between the parties. This type of relationship between contracting parties, known as a confidential relationship, was advanced by the Supreme Court of Georgia, as follows: "Any relations shall be deemed confidential...where one party is so situated as to exercise a controlling influence over the will, conduct, and interest of another; or where, from similar relation of mutual confidence, the law requires the utmost good faith; such as partners, principal and agent, etc." (*Davis v. Carpenter*, 1981).

A confidential relationship carries a higher level of duty than the archetypal relationship but that duty is breached by less egregious behaviour. For the courts to find a breach of duty on a contract expressing a confidential relationship, there need only be a showing that the stronger party exploited its relationship to take commercial advantage of the weaker party through intentional misrepresentation of material facts or a constructive fraud. It is not necessary to show actual fraud.

A fiduciary is one with superior knowledge and experience who is bound by a duty of trust and confidence to do what is in the best interest of another. The fiduciary first appeared in common law in the English case of *Keech v. Sandford* (1726). Exploring the contours of fiduciary duty to a minor child, that case established that a trustee owes a strict duty of loyalty. More recently in

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<sup>1</sup> The AIA identifies nine pure integrated project delivery projects: Sutter Health’s Cathedral Hill Hospital of San Francisco and Fairfield Medical Office Building of Fairfield, California; the MERCY Master Plan Facility Remodel of Lorain, Ohio; the Lawrence & Schiller office remodel of Sioux Falls, South Dakota; the SpawGlass Regional Office of Austin, Texas; the Autodesk, Inc. interior renovation in Waltham, Massachusetts; Cardinal Glennon Children’s Hospital Expansion of St. Louis, Missouri; the St. Clare Health Center of Fenton, Missouri; and Encircle Health Ambulatory Care Center in Appleton, Wisconsin.

the U.S., Chief Judge Cardozo established a strict standard of fiduciary conduct, asserting “Many forms of conduct permissible in a workaday world for those acting at arm’s length, are forbidden to those bound by fiduciary ties. A trustee is held to something stricter than the morals of the market place” (1928). The reasoning in *Meinhard* was very similar to the reasoning found in *Keech*: the fiduciary is bound by the rule of undivided loyalty that exists to reinforce the integrity of trusting relationships (*Meinhard v. Salmon*, 1928).

A fiducial relationship carries the highest level of duty but it can be breached by the slightest error of judgment. For the courts to find a breach of duty on a contract expressing a fiduciary relationship it is necessary only to show that the contractor did not act in the owner’s best interest. It is not necessary to show fraud, constructive fraud or misrepresentation. It is only necessary to show that the contractor’s act or failure to act, even when clearly communicated to the owner and competently performed, was not in the owner’s best interest.

The fiduciary relationship, the confidential relationship, and good faith and fair dealing are similar in that they all require attention to the interest of another. They differ in the degree that one party must subordinate its own self-interests. The fiduciary must completely subordinate its own self-interest to the interest of another. Good faith and fair dealing does not require subordination of self-interest as long as the interest of another is not abused. The confidential relationship falls somewhere in-between.

To know that a contractual relationship is archetypal, confidential or fiducial is to know what level of duty is expected and how to comport oneself so as not to breach that duty. Unfortunately, construction contracts rarely provide such specificity. We can, however, identify express words in construction contracts that place heightened duties upon contractors. For now, we define heightened duties as an attention to the interests of the owner that exceeds that of an archetypal relationship without specificity as to whether that obligation rises to the level of confidential or fiducial.

## **4. Contractual Expressions of Heightened Duties**

A typical expression of heightened duties is found in §1.2 of AIA Document A133™ – 2009 *Standard Form of Agreement Between Owner and Construction Manager as Constructor where the basis of payment is the Cost of the Work Plus a Fee with a Guaranteed Maximum Price*, which states in pertinent part:

“§ 1.2 Relationship of the Parties - The Construction Manager accepts the relationship of trust and confidence established by this Agreement and covenants with the Owner to cooperate with the Architect and exercise the Construction Manager’s skill and judgment in furthering the interests of the Owner...” (American Institute of Architects [AIA], 2009).

*Table 1: Occurrence of “trust and confidence” language in AIA Standard Form Contracts*

<b>Document</b>	<b>Purpose</b>	<b>Clause</b>
A101-2007	Cost + Fee with GMP	Art. 3
A103-2007	Cost + Fee without GMP	Art. 3
A133-2009	CMAR Cost + Fee with GMP	§ 1.3
A134-2009	CMAR Cost + Fee without GMP	§ 1.2
A141-2014	Exhibit A (Cost + Fee Design-Build)	§ A.5.6
A295-2008	IPD General Conditions	§ 9.1.3

The words “relationship of trust and confidence” are words in the art of law that infer heightened duties. Table 1 lists other occurrences of identical expressions of “trust and confidence” elsewhere in the AIA suite of contract documents. Heightened duties are inferred in DBB, DB, CMAR and IPD contracts. In each case these heightened duties are associated with the cost-plus pricing method.

## 5. Court Findings on Heightened Duties

At first glance, interpretations by U.S. courts of contractual language such as that found in AIA Document 131 §1.2 are mixed. In some cases a fiduciary relationship was found while in others it was not. However, there is a coherent pattern of decisions. The facts of each case at bar appear to have more influence on the court’s decisions than the express contract language.

On several occasions U.S. Courts have found a heightened duty in construction contracts with language similar to AIA’s A133 §1.2. In *Henson v. Barker* the Florida Court of Appeal found that AIA trust and confidence language in a cost-plus contract with a GMP for construction of an 8-unit condominium project placed a heightened duty on the contractor “to disclose any latent defects in construction that would materially impair the value of the structure” (1994). In *A.A. & E.B. Jones v. Boucher*, the owner, who was having a house built on a cost-plus basis, was confronted with a \$593,878 bill against a GMP of \$250,000; an architect that died during construction; a contractor that kept ramping up the change orders; and no way of knowing what was being billed for the lack of detail on the invoices (1974). In *Jones v. Hiser* the contractor, building a home on a cost-plus basis with an initial estimate and no GMP, did not bother to track costs or communicate cost changes to the owner until the end of the project (1984). In both *Boucher* and *Hiser* the courts found that the contractors acted in bad faith. While they did find that the express words of the contract created a fiduciary duty, that finding was only used to support their finding of bad faith. Typically, the breach of a fiduciary duty requires more than the absence of fraud or misrepresentation. Bad faith appears to have been that something extra.

Several U.S. Courts have found no heightened duties within agreements negotiated between contractors and sophisticated business owners. In a dispute over cost overruns, the Superior Court of New Jersey found no heightened duty on a cost-plus-fixed-fee contract for construction of a factory outlet store because the owner was a Real Estate Investment Trust [REIT] whom

employed an experienced Vice-President of Construction (*Avon v. Martin*, 2000). Despite language similar to the AIA's trust and confidence language, the court held that the contractor did not have "superior power, knowledge or control over the terms" of the work (*Avon v. Martin*, 2000). In *Eastover Ridge v Metric* the Court of Appeals of North Carolina found no heightened duties, despite AIA contract language, on a negotiated cost-plus contract where the architect had agency authority and extensive duties on behalf of the owner for the construction of 216 apartment units, a clubhouse, a pool, tennis courts, a maintenance building and landscaping (2000). The *Eastover* court attributed sophistication to an owner who hired an architect as his agent (*Eastover Ridge v Metric*, 2000). In a dispute over a verbal cost-plus contract to build a dream home valued at over \$4,000,000 the Wyoming Supreme Court did not find a confidential relationship because the owner was a successful and sophisticated businessman (*Garrison v. CC Builders*, 2008). The same outcome would likely have been found had there been a written contract with AIA trust and confidence language.

We can surmise from this that when the owner is a sophisticated builder or becomes so by virtue of hiring a professional architect and the contractor lacks power, knowledge or control over the terms of the work, the courts will find no heightened duties. Express words of trust and confidence in a construction contract will not alter that prescription.

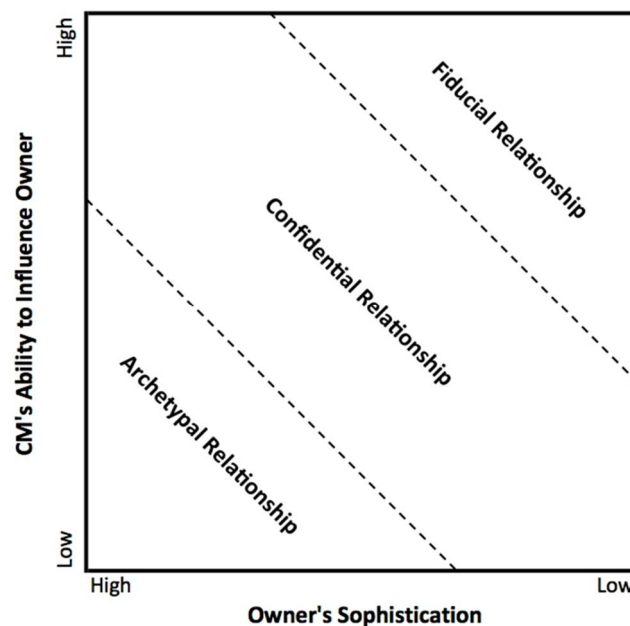
On several occasions U.S. Courts have found a heightened duty in construction contracts that lacked express trust and confidence language. In *Hitt v. Smallwood* a contractor with a fixed price contract to build a garage for a homeowner entered into a contract to do additional work on a cost-plus basis. The court found that the contractor had a heightened duty to keep accurate records (1926). In *Romine v Rex Darnall* a fixed-price contract to construct a home was found to be a cost-plus contract with a fixed fee and the appellate court found that cost-plus contracts include an implicit condition that contractors will "make every reasonable effort to minimize costs" (1976). In *Shaw v. Bula* the Missouri Supreme Court found for the homeowner because records produced by the contractor were not sufficiently accurate (1949).

All three of these owners were homeowners. A homeowner will not be presumed sophisticated and a contractor will be presumed to have superior knowledge of construction and power over the terms. There was evidence of misrepresentation, through either commission or omission, by all three contractors. A showing that a stronger party exploited its relationship to take commercial advantage of a weaker party through intentional misrepresentation of material facts establishes a breach of a confidential duty. Although these courts found heightened duties they did not choose to characterize this duty as a confidential duty.

The facts of any particular case appear to influence the court's propensity to find that contractors have heightened duties. When the owner is a sophisticated builder or becomes so by virtue of hiring a professional architect and the contractor lacks power, knowledge or control over the terms of the work, the courts will find no heightened duties. Express words of trust and confidence in a construction contract will not alter that prescription. The courts may find the heightened duty of a confidential relationship or the strict duty of a fiduciary relationship with or without express contractual language to that effect. Figure 1 graphically illustrates the propensity to find

archetypal, confidential or fiducial relationships along two axis: the CM's ability to influence the owner; and the level of the owner's sophistication.

The courts tend to define the duty that was breached by the egregiousness of the contractor's behaviour, not the other way around. Breach of a fiducial relationship is implicated when the only evidence is bad faith. Breach of a confidential relationship is implicated when the evidence shows misrepresentation or constructive fraud. Breach of an archetypal relationship is implicated by evidence of actual fraud.



*Figure 1: Heightened Duty Implications*

## 6. Conclusions

In a construction contract expressing an archetypal relationship the contracting parties are held to an implied covenant of good faith and fair dealing. For the courts to find a breach of that implied duty the aggrieved party would have to show actual fraud. A construction contract expressing a confidential relationship carries a higher level of duty than the archetypal relationship but that duty is breached by less egregious behaviour. For the courts to find a breach of duty on a contract expressing a confidential relationship there need only be a showing that the stronger party exploited its relationship to take commercial advantage of the weaker party through intentional misrepresentation of material facts or a constructive fraud. It is not necessary to show actual fraud. A construction contract expressing a fiducial relationship carries the highest level of duty but can be breached by the slightest error of judgment. For the courts to find a breach of duty on a contract expressing a fiduciary relationship it is necessary only to show that the contractor did not act in the owner's best interest. It is not necessary to show fraud, constructive fraud or misrepresentation. It is only necessary to show that the contractor's act or failure to act, even



when clearly communicated to the owner and competently performed, was not in the owner's best interest.

The facts of any particular case appear to influence the court's propensity to find that contractors have heightened duties. When the owner is a sophisticated builder or becomes so by virtue of hiring a professional architect and the contractor lacks power, knowledge or control over the terms of the work, the courts will find no heightened duties. When the owner is unsophisticated and the contractor has power, knowledge or control over the terms of the work the courts may find the heightened duty of a confidential relationship or the strict duty of a fiduciary relationship with or without express contractual language to that effect. Figure 1 graphically illustrates the propensity to find archetypal, confidential or fiducial relationships.

Finally, the courts tend to define the duty that was breached by the egregiousness of the contractor's behaviour, not the other way around. Breach of a fiducial relationship is implicated when the only evidence is bad faith. Breach of a confidential relationship is implicated when the evidence shows misrepresentation or constructive fraud. Breach of an archetypal relationship is implicated by evidence of actual fraud.

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## Abstract

Schools are the most expensive public service after the social and health care in Finland. Education provided by the schools is essential to the renewal of the workforce and to the development of the national economy. Educational services are produced in a network of school facilities. The size of schools, the distance between them and the quality of the facilities are most important drivers of the quality and cost of the education. The article is based on empirical data from 19 primary and secondary school networks in Southern Finland. Networks studied have neither high quality nor reasonable cost. A simulation model was created to study the potential for enhancement of the networks. The model was created based on the fact that there is a connection between the size of the school and the average size of the classes. Savings were the differences between the given model and the present costs. Simulation models showed that there is a remarkable potential for savings by redesigning the networks. The savings of school networks varied between 775 €/per pupil to 3120 €/per pupil. The average saving was 134 €/per capita. On a national level the savings would be approximately 0,7 billion €/a year.

**Keywords:** school networks, school size, facility cost, educational economics

## 1. Introduction

Finnish schools are mainly owned and operated by municipalities. The State supports municipalities, but they are wholly responsible for arranging and offering education and other services. This article studies the cost and quality of Finnish primary and secondary school networks. There has been a lot of discussion about the quality and cost of individual units in Finland, but seldom about the whole network. However, it is the network, not the units which provide the service to the citizens. If equality between taxpayers and users are wanted a few well functioning units are not enough. The level and cost of service should be somewhat constant everywhere.

Finnish schools are small. The average size of all schools (primary and secondary) is 195 students in Finland (FNBE 2013) when in US, the average size is 550 (Keaton 2012). In EU countries median primary school size is approximately 350 students (Bolam 2000). US National Center for Educational Statistics considers 300 pupils the smallest category, 500 to 1200 is medium and over

1200 large category (Keaton 2012). There are no schools in Finland which are in Keaton's large size category.

Finland is sparsely populated country and there are many small schools in the rural areas. 41% of Finnish schools have less than 100 students when only 10% of the pupils study in them (FNBE 2013). Such a network of small schools is expensive, and there are serious doubts whether the small schools are able to provide high quality educational services. There is an ongoing debate about the benefits of the small schools to the pupils and to the community (Kalaoja & Pietarinen 2009). The amounts of small rural schools have dropped dramatically during the last decades (ibid.). The closures of small schools always raise fierce public debate, even though they impact only a minority of the pupils. The quality of larger schools or the network as a whole is seldom discussed.

What we are interested in is the quality and cost of the networks. This study is based on our work on 19 school networks in Southern Finland. We studied the cost of tuition, the cost and quality of the facilities and formed alternative or simulated models for networks. We were able to show remarkable savings as a difference between the existing networks and simulated ones.

## **1.1 Research questions**

The research tries to find an answer to following research questions:

1. What is the overall quality and cost of school networks in the municipalities studied?
2. What would be the ideal school networks for the municipalities studied?
3. What would it cost to build and operate such networks compared to the cost of operating the existing networks?

The costs of transportation were not included, because they are minimal compared to other costs.

## **2. Methodology**

Research is based on material gathered during the years 2011-2013 from 19 municipalities, population of which is a total of 450 000. The municipalities studied are small or medium size municipalities in Finland, population of which are between 2000 and 50 000 inhabitants. They form 8,34 % of Finnish population.

The empirical part is based on the simulation model. The simulation model was created to study the potential for enhancement of the networks. The simulation model was created based on the fact that there is a connection between the size of the school and the average size of the classes. The average class-size is one of the most important factor behind the total cost of a school, because teachers' salaries are the biggest single expense of a school and the amount of teachers in a school is dependent on the amount of classes. Using the simulation model, three different service

networks per city or municipality were created based on the school size and average class size. The simulation model is presented more carefully in 4.3.

## 2.1 Structure of the work

This research consists of 8 sections. Firstly, chapter three concentrates on the theory and introduce previous researches related to the topic. Chapter four focuses on the empirical part of the study. The chapter describes in detail the data collection, research method and simulation model. In chapter five the results of the study are presented and in chapter six results are discussed more carefully. Finally, in chapter seven strings are pulled together in the form of a conclusion.

## 3. Theoretical background/Literature review

Theoretical background of this study is divided into two sections. In the first section different kinds of networks are presented. The section also introduces optimization methods for school network planning and typical characteristics of the school networks in Finland. The second section concentrates on size of the units i.e. how to school size and class size affect learning outcomes.

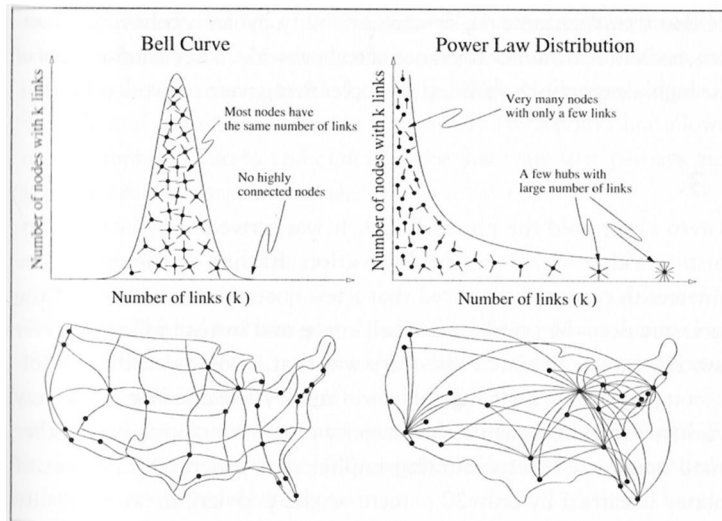
### 3.1 Networks

According to Merriam-Webster (2016) dictionary network is “an interconnected or interrelated chain, group, or system <a network of hotels>”. A group of schools owned by a municipality form a network because:

- they are interrelated: there is a limited number of students and they all have to go to a school, if one school grows bigger, the others have to decrease in size
- they are interconnected: there is a limit to a distance between two schools
- they form a system: not one school but all the schools are needed to provide school services to a municipality

Network theory studies all kinds of networks: air traffic networks, computer networks, social networks, to mention just a few. Typical to all kind of networks are that they are formed by nodes and links connecting the nodes. The basic type of a network is a *random network* (fig 1), where nodes and links are evenly distributed. Highway network is a typical example of a random network. The problem with a random network is that one has to go through many links to get from one place to another. This is called *network distance*: the amount of links between two places. (Barabási 2002)

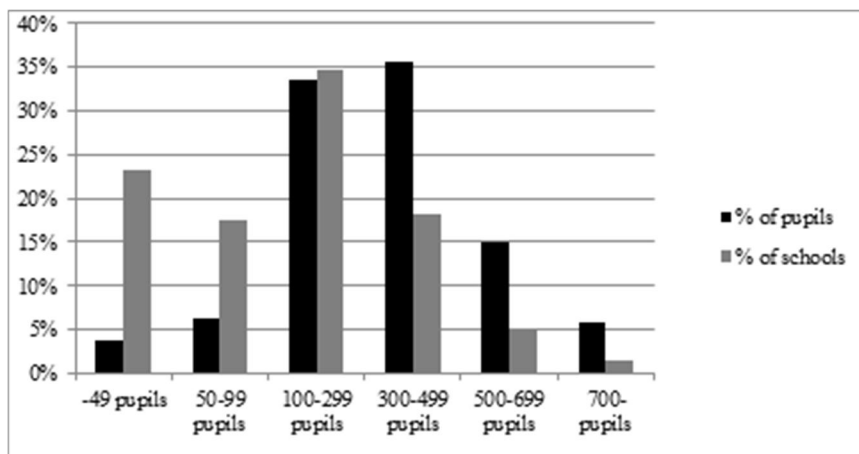
*The degree of separation* describes the overall quality of a network: how many links there are on average between two randomly chosen points. The degree of separation of the internet is nineteen: any two internet sites are nineteen links or “clicks” away from each other (on average). This is possible, because these networks are not random: there are short-cuts which make the world smaller.



**Figure 1.** The degree distribution of random network (top left) follows a bell curve. Most nodes have the same number of links, and nodes with a very large number of links do not exist. Scale-free network (top right) has a power law degree distribution of links. Most nodes have only a few links, held together by a few highly connected hubs (Barabási 2002: 71).

The internet has a small degree of separation, because it has “hubs”: super-nodes to which there is a link from most of the other nodes. A network based on few hubs and plenty of nodes with only a few links are called a *scale-free network*. Air traffic network is a typical example of a scale-free network. There are hubs like Heathrow and Paris De Gaulle and lots of unimportant small airports. If you can get to Heathrow from one of the small airports, you can get to almost anywhere from there. The internet is another example of a scale-free network.

Are public schools random or scale-free networks? Statistics of schools in Finland would suggest that they resemble more random network than scale-free one. If each pupil and each school are considered nodes, the distribution of links is the same as the amount of pupils in one school. The distribution of links in Finnish school network is more bell curve than a power degree distribution (fig 2)



**Figure 2.** The distribution of Finnish schools and pupils according to the schools size in 2013 (Finnish National Board of Education FNBE 2013).

## 3.2 School networks

### 3.2.1 Optimization methods for school network planning

Schools can be seen as the physical infrastructures used to produce educational services. Together with teachers, whose responsibility is to supply labour for the process, schools constitute the determining production factors used in educational sector. (Antunes & Peeters, 2000) The main target of educational network planning is to satisfy demand as much as possible. When that target is reached, the objectives will generally involve maximizing socio-economic benefits which is basically the same as minimizing costs. There can also be other objectives such as maximizing accessibility, which has been the main idea behind the development of the Finnish compulsory school network (Kuikka, 1996; Antunes & Peeters, 2000)

From the society point of view, one of the key problems in the educational sector is how the educational network should be planned so that it could serve educational demand in a certain region in the short, medium and long term. However, during the last decades, planning processes of educational networks have become increasingly complex. The educational network planning problem consists of many questions which should be solved: where schools should be located, what their size should be, which schools should be kept open and which ones should be closed, whether it is necessary to build new schools, what class sizes should be and so on. (Antunes & Peeters, 2000; Teixeira & Antunes, 2008) The planning problem has been researched on general level by several authors (see e.g. Erlenkotter, 1967; Roodman & Schwartz, 1975; Roodman & Schwartz, 1977; Fong & Srinivasan, 1981; Van Roy & Erlenkotter, 1982; Jacobsen, 1990; Shulman, 1991; Marianov & Serra 2002). Two separate research fields have focused on studying school network problems: “multi-regional capacity expansion” and “dynamic facility location”. These approaches are based on different kinds of mathematic optimization models which try to

determine optimal network structure. (Erlenkotter, 1967; Roodman & Schwartz, 1975; Roodman & Schwartz, 1977; Fong & Srinivasan, 1981; Van Roy & Erlenkotter, 1982; Jacobsen, 1990; Shulman, 1991; Marianov & Serra 2002). The literature review shows that there are also several articles which deal specifically with school networks. Henig & Gershak (1986), Greenleaf & Harrison (1987), Tewari & Jena (1987), Viegas (1987) Beguin et al. (1989), Pizzolato (1994), Antunes & Peeters (2000) and Teixeira & Antunes, (2008) present different kinds of optimization models for school network planning purposes, just to mention a few. However, the optimization models are typically very detailed and contain just a few variables, are designed for specific conditions, respond for specific needs, or contain other restrictions. They are often too complex for practical planning purposes.

### **3.2.2 School network in Finland**

The main idea behind the development of the Finnish compulsory school network has been to have schools close to the pupils which mean that the distance from home to school should be less than 5 km. This has led to a situation where almost every village in rural area has its own school. However, reduced birth rates, migration, changes in the economic structure, and improvement of rural road conditions started the closure wave of small rural schools in the late 1960s. The founding of the current comprehensive school system which ensured equal educational opportunities for all citizens improved the position of small rural schools for a while, but deep recession at the end of 1980s and early 1990s put the future of the small rural schools under threat. (Kuikka, 1996; Laukkanen & Muhonen, 1981; Kalaoja & Pietarinen, 2009)

In the early decades of the 2000s the demographic structure has changed in Finland. The National Board of Education (2004) predicted that the number of children of compulsory school age will fall approximately 10 % in every ten years at the beginning of the 2000s. In addition the trend towards rural-urban migration intensifies and regional centralisation will continue. (National Board of Education, 2004). Also the economic difficulties of Finland due to the downturn of past years create pressure for savings in public expenditure. In addition, Finland is already sparsely populated country (340 000 km<sup>2</sup> with population of approx. 5 million) so it is evident that there will be the growing need to cut the costs of the school network in Finland. To make the cost savings possible the unit size of schools needs to be increased and more effective school network to be planned. (Kalaoja & Pietarinen, 2009)

## **3.3 Size of units and economies of scale**

Size of units is closely related to the term *economies of scale*. The basic idea behind economies of scale is that enterprises can get the cost advantages due to size or scale of operation. Increasing the size of units typically leads to economies of scale because fixed costs are spread over more units of outputs. In the educational unit context, economies of scale means that fixed costs could be spread over a larger pupil base (Lee & Smith, 1997). In this chapter optimal sizes of educational units and impact of a class size on learning outcomes are presented.



### **3.3.1 The optimal size of a school**

According to Leithwood's and Jantzi's (2009) review of 59 post-1990 studies related to school size, pupils in small schools perform better than pupils in large schools. There is a lot of evidence in favour of smaller schools in the studies. However, the term "small school" and "large school" vary between the studies so it would make more sense to ask what the optimal size of a school is and is there difference between the optimal size of an elementary school and a high school (Cotton, 1996; Lee & Smith, 1997; Leithwood & Jantzi, 2009)

The exact size of an optimal school is difficult to determine, because the optimal school size depends on many different variables such as diversity of pupil background and differences between elementary schools and secondary schools. In an elementary school, where lots of pupils have diverse disadvantaged backgrounds, the size shouldn't be more than 300 pupils. In an elementary school with heterogeneous or relatively advantaged pupils the size should be smaller than 500 pupils. The size of an elementary school, where pupils are of diverse or disadvantaged background, should not be more than 600 pupils and with heterogeneous or relatively advantaged pupils, the size should be smaller than 1000 pupils. (Cotton, 1996; Lee & Smith, 1997; Leithwood & Jantzi, 2009)

In the previous paragraph the recommended upper limits of school sizes were presented, but there are minimum limits as well. Where the bigger schools tend to be more formal and bureaucratic, reducing school size too much leads to constrain courses and to reduced ability to respond to the special needs of pupils (Lee & Smith, 1997). Many researchers have reached the conclusion that an appropriate and effective size for an elementary school is 300-400 pupils and for a secondary school 400-800 pupils. (Cotton, 1996; Lee & Smith, 1997; Lee & Loeb, 2000). According to these studies 76% of Finnish schools are undersized.

### **3.3.2 The impact of a class size on learning outcomes**

It is very typical that parents and teachers assume that reducing class size leads automatically to better learning outcomes. It increases pressure on politicians to reduce class sizes or at least prevent them from increasing in many countries, also in Finland. (Pedder, 2006) Class sizes are one of the most discussed and most researched topics in pedagogical field of science. It is easy to find arguments for and against the claim that reducing class sizes would lead to better learning outcomes. Those who support class size reduction typically argue that reducing class size leads to higher quality instruction, student-centred teaching, more individualized instruction, fewer disruptions and so on. On the other hand, there is a huge amount of studies which claim that there is no evidence that reducing class size would lead to improved learning outcomes. (Hattie, 2005)

One of the most impressive and the most discussed study on class size was Project STAR (Student-Teacher Achievement Ratios) which began in Tennessee in 1985. Project STAR involved 6500 students in 329 classrooms in 79 schools. The students were divided into a regular class (22-26 students) or to a small class (13-17 students). The students were held in classes of same size for the next 3 years and teachers didn't get any special instructions for teaching different size of classes. The study showed that reducing class size had only a small effect on learning outcomes. The overall effects were 0,15-0,27 in favour of small classes on a scale of 0,0-1,0 according to a

meta-analysis of Project STAR. The benefits of small classes were greater for students who had worse socio-economic background. (Finn & Achilles, 1990; Word et al., 1990; Finn et al., 1991; Achilles, 1999, 2002; Ritter & Boruch, 1999; Achilles & Finn, 2000; Achilles et al., 2002).

Also the other studies after Project STAR have lead to the same kind of results. Typically the overall effects of class size reduction has been something between 0,1 and 0,2. For example Goldstein et al. (2000), Dustmann et al. (2003), Johnson et al. (2004), Blatchford et al. (2005) and Urquiola (2006) have studied the impact of learning outcomes when reducing class size from 25 to 15 pupils and they have come to a 0,1-0,2 effect-size. The effect-size of class size reduction could be considered small or even tiny, when compared to many other possible enhancement solutions. Hattie (2005) has listed 46 influences on student achievement and the place of class size (place no. 40) is clearly among the smallest effect-sizes. Average effect-size of different influences on learning was 0,40 according to Hattie's meta-analyses. One of the most popular explanations of why effect-size of class size reduction is so small (0,1-0,2) is that actually teachers of smaller classes adopt the same teaching methods they use in larger classes and are not optimizing the opportunities of fewer students in classroom. (Hattie, 2005) It can be said that class size reduction is an expensive educational reform, its positive effects on the learning outcome are uncertain and there is no scientific evidence that smaller class sizes automatically lead to better learning outcomes.

## **4. Methods**

### **4.1 What are the quality and cost of a network?**

In this study the quality and cost of a network consists of:

#### The quality and cost of the individual units and buildings

- The technical quality of the buildings and other constructions
- The quality of the individual buildings measured by square meters per student
- The cost of the buildings measured by the cost per square meter or cost per pupil
- The cost of the individual operational units measured by the cost per pupil

#### The quality of a each municipal school network of units and buildings

- The variation of the quality of the whole network of buildings measured by square meters per pupil or child
- The variation of the cost of the individual building units measured by the cost per sq meter or cost per pupil
- The variation of the cost of the individual operational units measured by the cost per pupil

The cost or length of transportation to and between units is not part of this research. The costs of transportation are minimal compared to other operational costs.

## 4.2 Empirical data

Research is based on material gathered during years 2011-2013 from 19 Finnish municipalities population of which is 450 000 together. The municipalities studied are small or medium size municipalities, population of which are between 2000 and 50 000 inhabitants. They form 8,34 % of Finnish population.

## 4.3 Simulation model

Usually school networks are approached from the inductive point-of-view: the enhancement starts from the existing school networks. Existing schools are analyzed and the proposals for embetterment are about closing units or creating new ones. However, this approach has some weaknesses. The schools are built for multiple reasons throughout the one and a half century history of Finnish public education. Nobody would build the school network today the way it has been built. In philosopher David Hume's words, we cannot derive "ought" from "is".

We have chosen a more deductive kind of an approach. Instead of existing school facilities we take the existing population only as the starting point. We do not speculate with the future changes in population but try to answer the question: "What would the quality and expenses be if we had built a more effective network in the past?" This gives us a possibility to compare today's expenses with what they *ought to be*. This method we call "a simulation model". The savings of a model are the difference between the existing costs and the possible costs.

The models are created based on the fact that there is a connection between the size of the school and the average size of the classes. The average class-size is the one of the most important factor behind the total cost of a school. Teachers' salaries are the biggest single expense of a school and the amount of teachers in a school is dependent on the amount of classes.

The amount of class series in a school is an important variable. The bigger the school, the more classes it has on any given grade (i.e. 1A, 1B, 1C, 1D and so on). The more classes a school has in one grade, the higher the average size of a class can be without any one class being oversized.

Three different models per municipality were created based on the school size and average class size. The new schools were sized ideally only based on the population data in each area. There operational costs were calculated. All of the school buildings were sized according to the Finnish norms. The facility cost per m<sup>2</sup> was the same as the existing cost, so all of the savings resulted from the diminished area. Simulation models were validated by comparing the results with the school size and cost database of Finnish Ministry of Education.

The savings in central costs (administration, catering, ICT and so on) were included. The investments needed to build the new networks were calculated on following assumption:

- half of the buildings would be either new or extensions to existing facilities

- half of the buildings would be completely renovated old buildings and the rate of their repair would be 80%

## 5. Results

### 5.1 The age of the facilities

More than 50% of the facilities studied are more than 40 years old. Only one quarter of the facilities were built after the year 1990. Half of the schools were built after the year 1970 and half of the day-care centres were built after the year 1990 (appendix 1).

### 5.2 Indoor air quality

According to the user surveys more than 25 percent of the pupils are studying in facilities which have serious indoor-air problems. Only 33% were satisfied with the indoor air quality.

### 5.3 Amount of space

According to Finnish norms there should be between 7,5 - 10 m<sup>2</sup> of net floor area per pupil in schools. Finnish norms allow much more space per user than many other norms. According to British Metric Handbook (Littlefield 2005) there should be 3,8 gross m<sup>2</sup> per pupil plus additional 200 m<sup>2</sup>.

In the data there are no networks even near the norm. The smallest average space in a school network is 14 square meters and the largest 20 square meters. The average is 14,37 m<sup>2</sup>. There is plenty of space in Finnish schools. This could be seen as an asset, but the problem is the great variation. In the whole data the amount of space per pupil varies between 3 m<sup>2</sup> to 57 m<sup>2</sup>.

Does more space per user always mean higher quality? The amount of space can be seen as a benefit only to a certain extent. After certain limit the interaction between individuals suffers due to long distances. According to the user survey there seems to be little correlation between the amount of space and user satisfaction. The huge variation inside networks cannot be seen as a positive factor. The space is one important resource which should be shared in equal amounts between users.

### 5.4 Cost of facilities

The average cost of facilities (capital costs not included) was 61,5 €/per gross m<sup>2</sup> a year. The least expensive network cost 46,2 €/per gross m<sup>2</sup> a year and the most expensive network cost 114,3 €/per m<sup>2</sup> a year. The highest school building was 223 € and the lowest 27 €/per year. Expenses were lower and the variation smaller in bigger units. Bigger units cause less travelling between the units for facility staff, less maintenance objects and so on than smaller units.

Cost per pupil is product cost per m<sup>2</sup> and amount of m<sup>2</sup> per pupil. Because of the excessive use of space, the cost of facilities per pupil was high in all networks. The average expense per pupil was 1,218 €/per year. The lowest expense was 216 € and the highest 3,810 €/per pupil.

The cost per m<sup>2</sup> is an indicator of the effectiveness of the maintenance organisation and the quality of the structures. However, the most important factor is the total cost per user in a year. The goal of a municipal organization is not to own property but to provide services of high quality on reasonable cost. Whatever measurement we use, the conclusion is that the facilities are too expensive and the variation of the cost is too big.

## 5.5 Cost of education

However, the cost of facilities is only 20%-25%<sup>1</sup> of the total cost according to our database of 19 municipalities. The biggest expense is the cost of education. This includes salaries, meals<sup>2</sup>, transportation, administrations and so on, salaries being the biggest single cost. The cost of education varies between 4,500 €/a year per pupil to 32 000 €/a year depending mainly on the size of the school.

## 5.6 Savings

Simulation models were made for all 19 municipalities. The savings of school networks varied between 775 €/per pupil to 3 120 €/per pupil. The average saving was 134 €/per capita, which would mean one percentage point lower taxes. This would mean more than 2,7 M€ yearly savings in a city of 20,000 inhabitants. The savings are big enough to allow complete replacement or renovation of the entire network of public building infrastructure.

On national level the savings would be 0,73 billion €/a year. The investment needed would be 1868 €/per capita. On national level it would mean 10,2 billion € investment. There would be 3,7 million gross square meters smaller area in buildings, which would have a great impact on carbon footprint.

## 6. Discussion

The variation and the level of the cost per pupil of either the facilities or the education are unacceptable. Citizens pay the same taxes and some of them get considerably more services per pupil than the others. The quality of services is often related to smaller and less effective units. Many factors of higher quality service environment are only present in reasonably sized units (better ICT, work teams, student support and so on). There is a serious doubt whether the quality

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<sup>1</sup> Including capital costs. The expenses are only 10%.

<sup>2</sup> There are free meals in all Finnish schools and day-care centers for everybody

of the services has any correlation with the money spent, which makes things even worse. The networks studied have neither high quality nor reasonable cost.

If the service networks had been designed only based on the demography and optimization of the size of the units they would consist of a few larger units in urban centres, accompanied by medium size units in rural areas. No school should be smaller than 300 pupils

This kind of network would resemble scale-free network (Barabási 2002) and would be less vulnerable to either decline or increase of demand. The present networks are random ones based on the optimization of the distance. Distances have lost their importance today, due to downfall of transportation cost and digital revolution.

## 7. Conclusions

The costs related to facilities are only 20-25% compared to the operative costs. The main conclusion of the study was that the service structure should be studied and planned first; the facilities have only a supportive function. This has not been the approach in municipalities so far. The focus has been on individual buildings and their construction, the operational school networks have been forced to fit into the existing building network.

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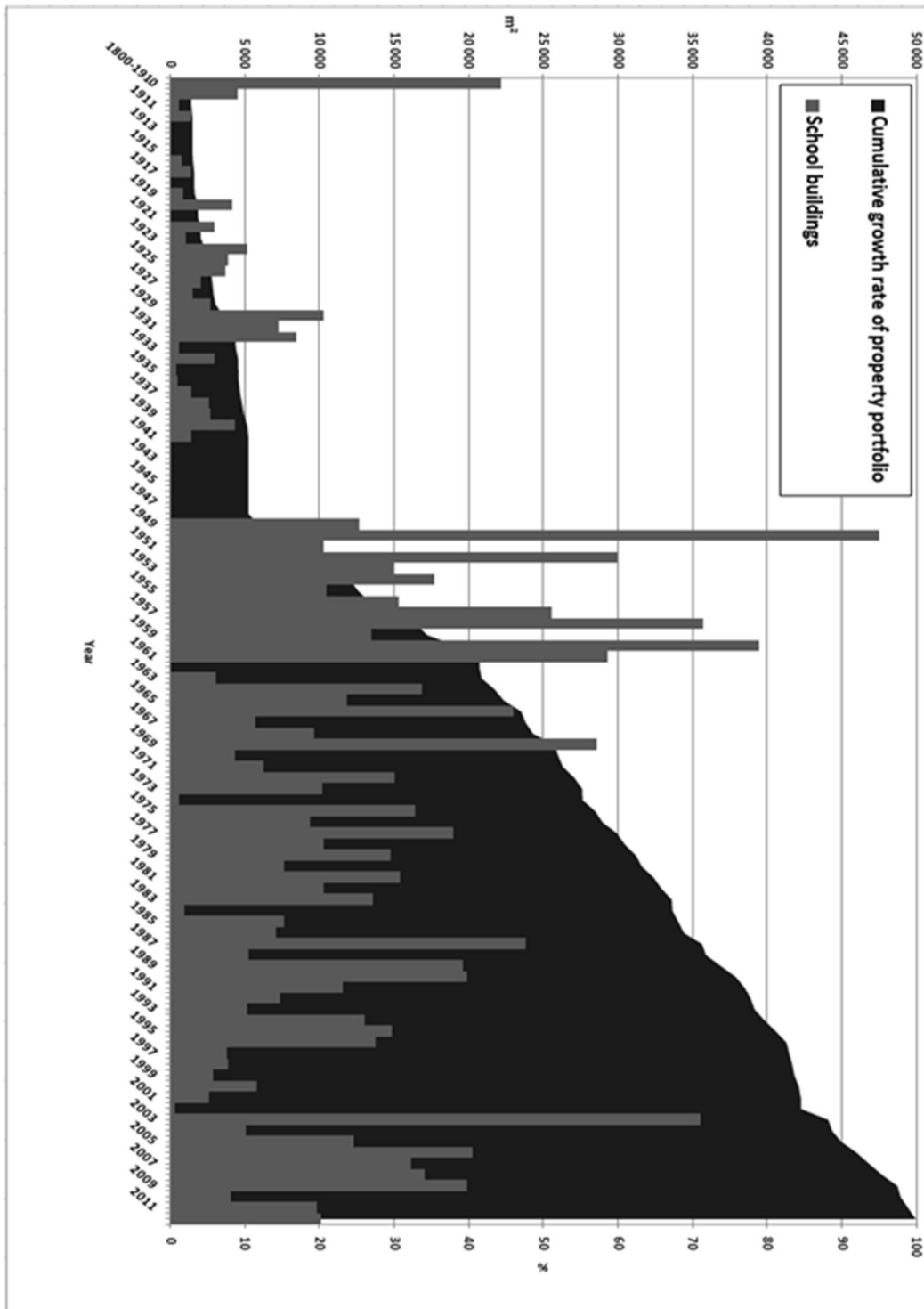
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## Appendix 1.

Age distribution of facilities per square meter and their cumulative age.



# **Factors Affecting the Development & Implementation of The Structural Aspects of the Nigeria Building Code Amongst the Stakeholder's within the House Building Construction sector in the Lokoja Municipality**

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## **Abstract**

The failure of the Nigeria Building Code (BC) development and implementation for the structural house building construction process in the Lokoja Municipality to protect the buildings, occupants and the environment as a result of vested stakeholder interests reverberates with significant impacts on house building failures leading to fatalities. There have been 742 recorded deaths, 96 injuries and 63 building failures: three cases from 1976–1978, 19 cases from 1982–1995, and 42 cases from 2000 to 16 September 2014 in Nigeria. These cause investors to lose confidence and allow the entry of non-professionals into the industry. This paper identifies and examines the key factors that affect the development and implementation of structural aspects of house BCs, drawing on contextual analysis and international experience. This paper represents part of a large Ph.D. research project, focusing on the key internal and external factors affecting the development and implementation of structural aspects of a BC. This paper has identified a multitude of inter-locking key factors that affect BC implementation in Lokoja including legislation, absence of approved standards, lack of good leadership, lack of political interest or will, inadequate implementation processes, lack of code awareness, high poverty level, high professional fees and insufficient public dialogue. There are also causal factors involved, which impact risks associated with the non-implementation of the code on consumers and the development of industry and professional practice. These include corruption, professional rivalry, professional vested interest, inadequate capacity building, absence of professional involvement in decision making, lack of respect for the poor and public opinion, abuse of human rights and unemployment

**Keywords:** Building Code, Development, Implementation, Structural Aspects, Stakeholder

# 1. Introduction

Building codes (BCs), which stipulate minimum standards for building health, safety and the wellbeing of the occupants and their environments, have been in existence from the time humans began manipulating their own environment. The first recorded case that set a minimum standard for building practises was the Code of Hammurabi in ca. 3000 BC (Trombly, 2006). The non-implementation of Nigeria BCs, which set minimum standards for building practises, has caused severe consequences regarding structural building collapse in the house building construction industry in Nigeria (Olusola et al, 2011). Codes are designed to protect buildings from structural failure, and the people and property inside them from death and extreme adverse effects on health and safety. BC development laid a solid foundation on which professionals boast of their work meeting minimum standards in a particular jurisdiction (Ghosh, 2002). All houses and their construction and management stages are regulated by BCs, which seek to harmonise best practises, materials, methods and processes to achieve a building that is habitable (Ayedun et al, 2012).

The building process, from planning and design to construction and management, is very complex; therefore, it requires a very strong regulatory regime and compliance mechanisms to sustain expected standards. The emphasis on building construction with very little attention to planning, implementation and enforcement among the stakeholders can be regarded as tantamount to impropriety (Davidson et al, 2003). The responsibility for building plan approval rests with the department of urban planning at the Federal, State and Municipal levels in Nigeria, while the execution, supervision and management of the operational process for implementation rests within the development control department; who enforce the implementation and ensure that the professionals and owner comply with building code provisions (NBC, 2006). However, the enforcement; once it is adopted provides an opportunity for training regarding the required skills and new technology for enforcement, implementation and compliance encompassing all stakeholders in the house building construction process (Olusola et al, 2011).

This paper reports details from previous studies to identify and establish the key factors preventing the implementation of the Nigeria BC to structural aspects of house building construction in the Lokoja municipality, Nigeria. Various studies have outlined different factors affecting the implementation of structural aspects of Nigeria BCs such as lack of enactment (Obiegbo, 2008), poor leadership, lack of political will, poor implementation practices, (Fagbele, 2010), lack of code reference standard, lack of BC awareness (Dauda et al, 2012), insufficient implementation and approval of building

development processes, insufficient public dialogue and lack of innovative technology (Olagunju et al, 2013; Olusola et al, 2011). These studies have concluded that in order to overcome the challenges affecting the implementation of BC, the casual factors must be identified and uprooted to reduce the risks associated with poor house building construction practices. The aim of this paper is to identify and examine key factors that affect the structural aspects of BCs with respect to the casual factors and the subsequent risks to the consumer, professional practice and the house building industry in support of prior research findings.

## **2. BC features and their regulatory problems**

The BCs have different components that work together to ensure a building's safety, benefits, welfare convenience to all persons involved in building processes (CASA, 2012). Al-Fahad (2012) stated that the Productivity Commission (2004) presented the four aspects of BCs (see also NBC, 2006; Act, 2013: p.21; ICC, 2006; 2009): legislative (legal aspects of building rules and regulations), social (deals with the relationship of the people with respect to the code and the building environment), administrative (deals with BC administration and the discharge of its functions in any country) and technical (deals with technical requirements for pre-design, design, construction and post construction). With these features, clarifying any part of a problem that might arise can easily be achieved. These features are inter-connected; relating different features of the BC with associated problems that must be collectively resolved for improved implementation.

The Building Control requirements within Nigeria lie at the centre of an idea or discussion surrounded by a multitude of problems. The individual legal, administrative, technical and social problems affect the functionality of the BC. All problems are in a circle, indicating that all problems affect each other. To eradicate the BC problems, the legal, technical, social and administrative problems must be solved simultaneously, to not pollute the central idea of its basic objectives through their correspondences.

## **3. Structural Aspects of house Building Construction Process**

In current building practises within Lokoja municipality, the structural aspects of house building construction involve the following stages: from building design for approval by urban planning department to building construction to the monitoring and inspection by the development control department. Table 1 presents typical development planning permit procedures for building structural aspects approval within Nigeria.

Table 1: A summary of the building approval process within Nigeria

S/no	Approval process	S/no	Approval process
1	Submission of building plans and supporting documents	6	Charting of development plans into relevant plots to check if within the layout plans of the government information data
2	Initial scrutiny of the basic design and documentation requirements	7	Township, processing and endorsement of the plans
3	Registration of the plans for approval and inspection with receipt attached	8	Collection by the person that submitted the plans
4	Inspection of the site by development control to write a report based on standard regulation	9	Monitoring post approval
5	Payment of approval processing fees to further enhance the treatment of plans	10	Penalty for the contravention of approval process

Source: Building development control offices, December (2014)

The supporting documents to be attached to the complete set of building plans include: Environmental Impact Assessment report (for factory or industrial buildings), Site Analysis Report for all building plans, and Letter of Attestation<sup>1</sup>. The letter must include the name; professional qualification (must be member of Council of Registered Builder of Nigeria (CORBON) or Council for the Regulation of Engineering in Nigeria (COREN), a photocopy of the certificates, residential address and functional telephone numbers of the builders

### 3.1 Regulatory Enforcement Monitoring in the Current House Building Construction Process

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<sup>1</sup> Implementation policy started in 2011 by the Development Control Abuja and Lagos State for builders and engineers involved in the erection of multi-storey buildings, as a result of incessant collapse of buildings

Olaitan and Yakubu (2013) reported a field survey for developing areas of Lokoja. They presented a damming report on the regulatory failure and non-compliance practises of the building code provision. The survey is summarised as in table 2 below.

Table 2: A summary of Building regulatory failure & non- compliance practices

Building type	No. of houses observed	No. of building approval obtained	No. of visits by Development Control during construction	No. of architects, builders and engineers involved	Drainage provision	Road setback allowed	Total
Storey buildings							
BOldPQrts	5	1	0	1	2	1	10
GDM	5	2	0	2	1	0	10
Z8	7	2	0	0	0	5	13
Felele	15	4	0	2	1	2	24
Bungalows							
BOldPQrts	30	5	0	2	1	3	41
GDM	25	3	0	0	1	4	33
Z8	20	4	0	0	0	9	33
Felele	60	7	0	3	0	2	72
Total	167	28	0	10	6	26	237

Source: Adapted and modified from Olaitan and Yakubu , (2013: p.145)

Where: BOldPQrts=Back of old poly quarters, GDM=Gadumo, Z8=Zone 8

The study presented in Table 2 observed 167 buildings, of which, 28 buildings obtained approval, representing 16%. Ten had at least one professional, amounting 0.59%, and 0.0% of site visits were recorded for enforcement indicating a total regulatory failure of enforcement

### 3.2 Recorded Cases of Structural Building Failure

The figure below illustrates an example of recorded cases of building failure across the country. Bayo (1995, cited by Tanko et al, 2013), Kingsley (2010), Abimbola and James (2012) and author recorded a total of 63 structural building collapse: three cases from 1976–1978, 19 cases from 1982–1995, and 42 cases from 2000 to 16 September 2014 in Nigeria. There have been 742 recorded deaths, 96 injuries and 63 building failures. Fagbenle and Oluwunmi (2010) argued that professionals and non-professionals undermined the regulation of BCs for structural buildings because of inadequate legislation and unaccountability in the industry. The study recommended the life imprisonment as the minimum punishment for those involved in any building collapse.

## **4. Key Factors Affecting the Implementation of BC Structural Element Provisions**

The body of literature reviewed presented various factors that impede the implementation of the structural aspects of the building code provision. These factors include a lack of awareness of the NBC and a lack of legal framework. Dauda et al (2012) argued that the lack of awareness among the populace reduces the degree of compliance with the required regulations. The more people are aware of the existence of these regulations within their municipality the better; their awareness partly determines the extent to which people will comply with the regulations. Further, Dauda et al (2012) stressed that lack of legal framework makes legislative support difficult. Another key factor is uncontrolled urban growth. Abubakari and Romanus (2011) observed that urban growth was not adequately controlled due to the rapid, chaotic growth of cities during a rapid period of industrial development as witnessed in counties such as Nigeria. There was a massive exodus of migration to the cities in search of greener pastures, which created squatter settlements and informal sector activities that continued to grow because of implementation problems (Wafula, 2012). The increased urban pressure on buildings and facilities is due to a lack of government unplanned urbanisation in line with urban growth.

The majority of urban centres in developing countries are not planned, and where plans exist, enforcement is absent (Kimani & Musungu, 2010). An inadequate implementation process and manpower for enforcement is another key factor identified in reviews. Berrisford (2010) showed that unclear implementation procedures for structural aspects of buildings and inadequate technical manpower within the local authority to enforce implementation of building development were a serious challenge in African cities (Berrisford, 2010). The study observed that the local council had neither clear standards for implementing each of the structural aspects of the code provisions nor the technical expertise in the areas of building health inspectors. Absence of approved standards and laxity in the approval process also discourage developers to submit their drawings for approval and start development immediately without worrying about consequences of their actions. If the approval process can be hastened, barriers to the implementation of building regulations will be eliminated (Berrisford, 2010).

Lack of government directive and promotion is also identified as key factor hindering the development and implementation of the structural aspects of the BCs provisions in Lokoja Municipality. The development policies in developing countries have been characterised by failures



as a result of bureaucratic decisions, delays, poor specialised bodies, ineffective local institutions and staff, lack of institutional framework for development planning and the lack of or inadequate participation by the beneficiary population, as cited in many African countries – Botswana, Kenya, Zambia, Zimbabwe, Tanzania and Nigeria Berrisford, 2010). The federal government’s concentration of power has left local governments with no experts to drive policy formulation and implementation in an effective direction (Berrisford, 2010). Political Interference or lack of political will at all levels is also cited as another factor hindering the further development and implementation of building code provisions. Obiegbu confirmed that the government, both central and local council, lack commitment to building regulations, which has clearly been seen in the case of Nigeria’s BCs, which have come before the national assembly for decades without legal backing. In the opinion of Nyangweso, (2007), a high professional fee is also identified as a constraint to implementation. On average, each professional charges 3–15% of the total cost of house construction as professional fees. Land within a developing area (like Lokoja) costs N800, 000 (£2,858.01) for 450.00 m<sup>2</sup> of land. Such high costs may discourage developers to involve professional in the development of house building construction, thereby increasing the risk of building collapse much further (Berrisford, 2010).

Other factors that impede the development and implementation of BCs in developing countries are as follows; absence of a national building safety strategy, out-dated and incomplete building legislation, lack of data regarding the country’s building market and legislation requirements in both the public and private sectors, weak private-sector technological capability due to a shortage of adequately trained staff, out-dated bylaws, quality control and safety systems, inability to enforce building control and development Initiatives and underfunded regulatory agencies lacking skilled staff and other necessary resources, resulting in inadequate inspection, monitoring and certification capabilities (Fundi et al, 2011; Kimani & Musungu, 2010).

#### **4.1 Causal Factors/Impact Risk of Non-Implementation of BC Provisions**

A number of studies have identified casual factors associated with the poor implementation of building code provisions within Nigeria as a whole. For instance, Ayedun et al (2012) and Oyinola (2011) agreed that corruption at different levels of political leadership and amongst stakeholders impedes the implementation of standards in Nigeria. Corruption in Nigeria, as presented by the authors, comes in different dimensions: lack of quality education for children, election manipulation by money and bribery, and backdoor business decided in one man’s sitting room to steal public resources (Transparency International, 2013). The Civil Society Organisations Report (2008), Transparency International (2013), Ayedun et al (2012), Oyinola (2011) and others attributed the following reasons to corruption in Nigeria:

- Weak government corruption fighting institutions.
- Lack of access to public information.
- Pre-bargaining and negotiation.
- A low record of punitive punishment for corrupt officials.
- Insincerity of government.
- Insecurity of informants.
- Systemic disorder.
- Poverty.
- Nepotism

Lack of professional involvement in house building construction is another causal factor that impedes implementation. Omeife and Windapo (2013) argued that a lack of professional participation in house building construction affects the implementation of standards, thereby causing building collapse. Hence, Agapiou et al (1998), therefore, called for greater efforts to enhance the collaboration and coordination of all stakeholders working towards better housing for all. Professional rivalry and mutual suspicious are also causal factors. Agapiou et al (1998) upheld that stakeholders should develop cordial relationships for the interest of clients and projects, and denounce the current practises of opponent attacks, which exist in the construction industry. The study suggested that there should be an interest in making the relationships work to achieve the desired goals among stakeholders, recognizing that cordial working relationships may not be free from constraints, but closer ties among stakeholders in closing the existing gaps and wastages will go a long way in overcoming the obstacles to create trust and to reduce the cost of construction. The study highlighted some key factors for ‘effective partnership relationships’, such as “Compatibility among stakeholder, each stakeholder norms of practices, High degree of internal trust, Robust team building, Genuine openness towards those outside the partnership” Agapiou et al (1998: p.359). Another causal factor that impedes the implementation of structural aspects of house building is inadequate capacity building. Dixit (2008) stated that implementing BCs could be easy through capacity building by training all management, professionals, and artisans/tradesmen (etc.) to develop control. The risks associated with non-implementation of the BCs due to causal factors were incessant collapse of structural aspects of buildings, loss of investors in the sector, unplanned cities, and non-professionals in the industry, substandard building materials, and congestion of houses, blockages of drainages and roads, and environmental pollution.

## **4.2 Strategies to Improve the Implementation of BC Provisions within Nigeria**

Many authors have supported different models that could ease the implementation process among various stakeholders, including Pinder et al (2013) who stated that, if more adaptable buildings were constructed in terms of standard regulations, cost considerations and cultural considerations, the change in the mind set of stakeholders would help resolve a key issue through his model, the Virtuous Circle to Curb the Circle of Blame (Pinder et al, 2013). The model posits that government policies and regulations have a greater influence on the mind-sets of the people concerning choices of buildings. However, few studies have modelled how the regulatory enforcement design can be complied with effectively to balance the interests of all stakeholders. Compliance to Building Code requirements is fraught with difficulties if construction firms, Central and Local Government lack effective expertise to comply with regulatory requirements. The lack of expertise necessitates the need for a top-down approach to raise awareness amongst the multitude of professionals involved in the house building process, as well as artisans/tradesmen, house owners and the general public (Surya 2008), coupled with strengthening of the role & capacity of local government officials, academic institutions and NGOs in the implementation process. Agapiou (1998) highlighted the significance of capacity building through training and development of personnel, which would invariably enhance the implementation process of the structural aspects of BCs in the house building construction industry (see also Dixit, 2008). Agapiou (1998) stated that more emphasis should be on performance criteria for training instead of merely showing the syllabus to be covered and assessing the trainer. The trainer must design qualifications in line with the statement of competence via valid assessment of work performance. They must also monitor the inspectors, evaluate and verify the system for a successful implementation of the training programme that has recently began in the house building construction industry in Nigeria.

## **5. Conclusions**

What this paper aimed to achieve was to identify and examine key factors that constrain the development and implementation of BCs. It was observed that the structural aspects of the BC were not being implemented as a result of policy (administrative) and legislative failures from government agencies at all levels. These failures adversely affected the implementation of the technical features by the various professionals involved in the building construction process and, therefore, created lapses in the publicity of the BC. These were blamed on causal factors that

significantly increased building risks over time. It can be stated that the administrative features of BC policies are critically important to the development and implementation of BCs, and impact significantly government enforcement agencies (town planning boards, development control, etc.), professionals implementing technical features into their practices and others complying with the standards. If the key factors that affect the development and implementation of BCs must be eliminated, an effective policy design framework must be put into place to uproot and break the causal factor's shark-like teeth that grip the key factors. This paper suggested strongly that, taking into account the identified key and causal factors, an effective policy development and detailed implementation framework design showing what to do, who will do it, when it has to be done, how it should be done and time taken amongst the stakeholders would drastically reduce the impact risks on the industry and help solve the problem of non-implementation of the BC and incessant collapse of buildings. This paper has clearly presented a solution involving stakeholders' mind set change, partnership and collaborative working relationships, and mutual trust building to ease the implementation process and capacity building of stakeholders. The findings of this paper has identified that; systemic disorder including; high level of national corruption, professional rivalry/vested interest, inadequate capacity building amongst the stakeholder's through bureaucratic process impede the development and implementation of structural aspects of BC within the house construction sector in Lokoja Municipality, Nigeria.

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# Improving Early Stakeholder engagement process for Infrastructure projects

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## Abstract

Infrastructure construction projects engaged multiple stakeholders directly and indirectly during the pre-construction stages until completion. In large projects, stakeholders have varying needs, interests, rights and demands. Projects that actively engaged with their stakeholders are more likely to succeed. The main purpose of engaging the stakeholder is to ensure their needs and preferences are reflected in the outcome. Early stakeholder engagement creates the ability to gain first-hand information to improve project and community outcomes. Engagement can address challenges and better manage. This paper investigates improvements that can be made through the engagement process to improve project and community outcomes. This paper applies a qualitative research methodology based on interviews and observation from two case studies, comparing stakeholder arrangements in New Zealand and Malaysia. The comparative findings show the values of stakeholder engagement obtained during the pre-construction process. From the case studies, this paper highlights three main implications of early engagement showing that close engagement with the public; transparent information and better understanding of the design concept could improve project outcomes.

**Keywords:** early stakeholder engagement, stakeholders, engagement process, infrastructure projects, Malaysia, New Zealand

# **1. Introduction**

Large infrastructure projects are characterised by uncertainty, risks and complexity. Infrastructure projects can be politically sensitive and highly demanding (Cornick and Mather, 1999; Clegg et al., 2002; Cicmil and Marshall, 2005). Large infrastructure projects have a large number of stakeholders, complex procurement arrangements and tend to engaged multiple stakeholder with various interest, objectives, power and background (Cornick and Mather, 1999; Clegg et al., 2002; Cicmil and Marshall, 2005; Aaltonen, 2010). Involvement of internal stakeholders in an infrastructure project may range from simple consultation on design briefs to responsibility for the design of components, systems, processes, or services (Aapaoja, 2014). External stakeholders, who are those affected by the project being delivered, also need to be consulted. In comparison with the healthcare and education sectors, the development of public participation and stakeholder engagement in construction industry is still very rudimentary (Rowe and Frewer, 2005). However, a good process of engagement helps the project organisation develop good relationships with stakeholder. Marthur et al., (2008) stated that the construction industry should engage with stakeholders to determine what they need. The roles, needs and responsibilities of stakeholders impact on the time, cost and quality of a project. The more complex the developed project is, the earlier the stakeholder should be involved. Engaging the stakeholder, especially the community and public, as early as possible improve the chances of a good outcome. Literature has recognised the importance of involving stakeholders during the early stages of a project, although few techniques for assessing their needs have been developed and tested (Smith and Love, 2004).

This paper investigates improvements that can be made through the engagement process to improve project and community outcomes. The aim of this paper is to focus on identifying possible improvements in the process of stakeholder engagement in the planning stage of infrastructure projects. This study examines the early stakeholder engagement process that has been used in case studies in New Zealand and Malaysia which were analysed to find out best practice and compare practice.

## **2. The stakeholder engagement process**

### **2.1 Parties involved**

Winch (2007) classified stakeholders into three: project stakeholders, internal stakeholders and external stakeholders. Project stakeholders are those from the client organisation. Internal stakeholders are stakeholders in legal contract with the client. External stakeholders have a direct interest in the project includes public and private actors. Project and external stakeholders have the most influence on a project (Dix, 2010). Ward and Chapman (2008) pointed out that stakeholders are a main source of uncertainty in large construction projects where stakeholder entities, their claims and interrelationships at every project phases create project uncertainties. For instance, local and regional stakeholders are concerned with the influence of construction activities on their daily routine activities and life style and can use political relationships to affect outcomes (Ernzen et al., 2001; El-Gohary, 2006). The quality of a construction is also largely dependent on the appropriate performance management of diverse stakeholders, especially contractors and consultants (Sui Pheng and Ke-Wei, 1996). This means that, if



major parties of a contract are not committed to properly carrying out their responsibilities, it is likely to adversely affect the final project quality level (Heravitorbati et al., 2011).

## **2.2 Practices in the engagement process**

The methods of engagement with stakeholders depend on a range of factors, including stakeholder willingness to participate. Basic engagement methods for infrastructure projects include one-to-one individual meetings or group meetings. Karlsen (2002) discussed the engagement process in six steps: initial planning, identification of the stakeholder, analysis of the stakeholder involved, frequent communication, action taken and following-up. Young (2006) proposed with three stages involving identifying stakeholder, gathering information and analysing influences of stakeholders. Walker (2008) discusses the process of identifying stakeholders to prioritising stakeholders, visualising and mapping stakeholders, engaging them and lastly monitoring effectiveness of communications. While Jeffery (2009) suggested the process should extend from internal preparation and alignment, building trust, consulting, responding and implementing, monitoring, planning and understanding the stakeholders in the later stages of the project.

The process of engagement requires mechanisms and opportunities for stakeholders to provide a substantive input (Foo et al., 2011). Foo et al., (2011), reported that stakeholder engagement process may be one-way or two-way, depending on the flow of information where one way is information given to stakeholder through, for example, project exhibitions and presentations. Two ways includes seeking information and opinion from the stakeholder, such as dialogue sessions and customer satisfaction surveys. Previous research has supported the practice of engaging multidisciplinary stakeholders in two ways public engagement, especially in construction development projects (Hooton et al., 2011).

Engagement is part of the decision-making process. A systemic engagement process will improve stakeholder's understanding and improve decisions. As such, adverse reactions from stakeholders can be reduced. Public engagement is one of the most direct approaches to manifesting and resolving potential conflict and improving stakeholder's satisfaction (Rowe and Frewer, 2005). Leung et al., 2013 believed that different stakeholders have different types of power and interests on public engagement projects. Power inequalities and imbalanced interests, which create the potential to escalate conflict, often represent as critical barriers to meaningful engagement and engagement success (Prell et al., 2007).

Ng et al., (2012) stated that in developing countries, the engagement process is still regarded by some governments as a non-value adding task when it comes to infrastructure project. The study showed failure of some public participation exercises due to a lack of a systematic framework in the engagement process. Controversy and conflict may arise over the location, size and design of project if potential impact of a proposed project is not adequately communicated (Olander and Landin, 2005). Common issues arising among project managers in communicating with external stakeholders of projects is how and when to be engaged. An Early stakeholder identification program should be an initial stage in stakeholder engagement practice. Yang et al., (2011) claimed that challenges of the project manager are in the process of stakeholder identification and their needs, and formulating proper engagement strategies. Some stakeholders can be sensitive and sceptical. Some stakeholders believe that decisions

have been made before they are involved, giving a negative effect on the level of participation in the programme; including individuals participating in an antagonistic way or refraining from participation altogether (El-Gohary et al, 2006). Dix (2012) stated it is very important to acknowledge the potential conflict between the known roles as stakeholders and their legal and moral responsibility for their interests. This can be achieved through open communication and appropriate reporting system. From the management, it is a necessary to recognise issue of the stakeholders' who affected with the project. Identifying issues earlier could change the way of external stakeholders' action towards the project.

### 3. METHODOLOGY

This paper carried out case studies from two large infrastructure projects, one in New Zealand and one in Malaysia. The projects were a well-known expressway project in northland of New Zealand and a mega project of public transit railway in Malaysia. Semi-structured interviews took place with key, internal and external stakeholders of the projects. The external stakeholders including a non-government transportation agency, historic and cultural agency, community groups, councils and environmental groups, public community was undertaken. The focus of these interviews was to elicit feedback from the stakeholders on their understanding on the engagement process undertaken. It is also aimed to seek out their perception/satisfaction/view throughout the process, as well as improvements that could be made by the project client to improve the practice of stakeholder engagement. A profile of the interviewees can be found in Table 1. Initial discussions prior to the formal interview ensured that those selected were appropriate to represent the views of their respective groups, agencies or the community. The interviewees included a balance of those who supported, opposed and neutral towards the infrastructure scheme. The study was limited to the early stages/planning stage of the project, because this is where external stakeholders and community exerts the strongest influence on the project.

*Table 1 Profile of interviewees*

<i>Case studies</i>	<i>Stakeholder Code</i>	<i>Affiliation</i>	<i>Concern</i>	<i>Interest</i>
<i>Expressway project, New Zealand</i>	<i>SN<sub>A</sub></i>	<i>Project Manager</i>	<i>Alliance</i>	<i>Project</i>
	<i>SN<sub>B</sub></i>	<i>Stakeholder Manager</i>	<i>Alliance</i>	<i>Project</i>
	<i>SN<sub>C</sub></i>	<i>Advisor of national historic agency</i>	<i>Oppose in part</i>	<i>Historical heritage, culture</i>
	<i>SN<sub>D</sub></i>	<i>District community board</i>	<i>Oppose in part</i>	<i>Interchange and local connectivity</i>
	<i>SN<sub>E</sub></i>	<i>Community group member 1</i>	<i>Oppose in full</i>	<i>Own land, social effects</i>
	<i>SN<sub>F</sub></i>	<i>Community group member 2</i>	<i>Support in full</i>	<i>Expressway, interchange, local people</i>

	$SN_G$	Manager of regional council	Support in part	Local river, flood, land management
	$SN_H$	Affected School representative	Opposed in full	Sustainability and fairness
	$SN_I$	Representative of business organisation	Support in full	Good access, environmental mitigation
Mass rapid transit railway, Malaysia	$SM_J$	Stakeholder Director	Project owner	Railway
	$SM_K$	Project Manager	Project owner	Railway
	$SM_L$	Business owner	Support in part	Regular customer, new trading area
	$SM_M$	Community representative of High end residential	Support in full	Railway track, access to resident
	$SM_N$	Land owner representative of old trading area	Opposed in part	Relocation, acquisition
	$SM_O$	Shop owner representative of old historical building	Opposed in full	Demolition of historical building
	$SM_P$	Community representative of affected housing area	Support in part	Land acquisition, new houses
	$SM_Q$	Public transport user	Support in full	Railways

A prepared list of questions was used as a tool for face-to-face discussion. Interviews were recorded and transcribed typically lasted 30 minutes to 1 hour. The data analysis procedure involved converting raw narrative data (interview notes, audiotapes) into partially processed data (transcripts), which were then coded (with the aid of NVIVO software). Key steps in the stakeholder engagement process were then developed from the coding process. The process followed standard university ethics protocols for research.

## 4. Findings and discussion

### 4.1 Two cases: similar issues - the New Zealand Expressway project and the Malaysian Mass rapid transit system

This project is a key component of a number of national, regional and local transport strategies, policies and plans. This project includes the upgrading of State Highway 1 (SH1) between the Wellington Airport and Levin having been identified as a RoNS (Road of National Significance). It is stated in the

Government Policy Statement on Land Transport Funding as identified by the Government in May 2009. The expressway project in New Zealand portrays the extensive engagement process from 2010 until 2012. One of the objectives of Road of National Significance (RoNS) the 16 kilometres project aims to improve the connection of roadways in the Wellington and was procured by Alliance procurement method. A refine scheme design addressed urban form issues, following an extensive engagement process with the community and council.

The second case study of a mega infrastructure project is within the vicinity of Klang Valley, Malaysia. Klang Valley is the centred area of Kuala Lumpur, the capital of Malaysia, adjoining cities and suburbs in the state of Selangor. The Klang Valley mass rapid transit system is part of Greater Kuala Lumpur (KL) project, which will be part of the public transport system that aims to support the achievement of a vibrant Greater KL metropolis. This project is of 51 kilometres of railway including an integrated urban mass rapid transit system for greater connectivity for KL. The project is first phase of three phase project, total in overall distance of 150 kilometres long and is one of Malaysia's largest infrastructure project. Upon completion, the project could cover a radius of 20km from the city centre and when fully operational would serve up to two million passenger per day. This project was procured by the design and build delivery system.

## **4.2 The Process of engagement – initial/planning stage**

### **4.2.1 Initial stage in New Zealand Expressway project**

Involvement of stakeholders started early with a series of meetings with the stakeholders including the community and included writing to the affected stakeholders and announcements about the project in the national media such as national television and newspapers. At this stage, the project owner was offering the stakeholder information to assist them in understanding the project and telling the community and public about the project and affected area. Because of the early start, significant levels of interaction with stakeholders achieved.

During the first phase of the engagement process in 2009, scoping and corridor assessment, time was taken to inform and gain an understanding of the views of the affected community, key stakeholders, iwi (indigenous) group and other public members. The client delivered the method of community, stakeholder and general public engagement on the preferred route for a four-lane expressway. During inception stage the project consultation included responses to community concerns around the construction project. During this period, the agency worked with targeted group of stakeholders to clarify the project scope and process. The Early Start Team was established as a specialist team selected for their expertise along the affected area of the expressway project, and their ability to engage with the local community. Project constraints were identified from stakeholders such as impact on the town centre and Business Park, ground conditions, environmental impacts, local traffic impacts including pedestrian and cycleway. A Community Reference Group (CRG) was established with Terms of Reference including:, the invited member must be engaged with open-minded and informed dialogue, focus on real issues, focus on opportunities and benefits, different communities must be recognised, continuity through project phases with the community and disseminating project information to wider community. The CRG held workshops during which different options could be shared. Project expos were also held throughout the expressway project. Engagement included a series of expos and

exhibitions held several. Mock up models of the expressway was used to aid the understanding of the community and to picture the bigger idea of the expressway. The expos were a platform for discussion with the wider stakeholders. The client also established a local presence at the area and transformed a “shop front” into a Visitor Centre by the time construction started. The “shop front” was regularly staff by members of project. Other engagement methods used were web-based online discussion forums.

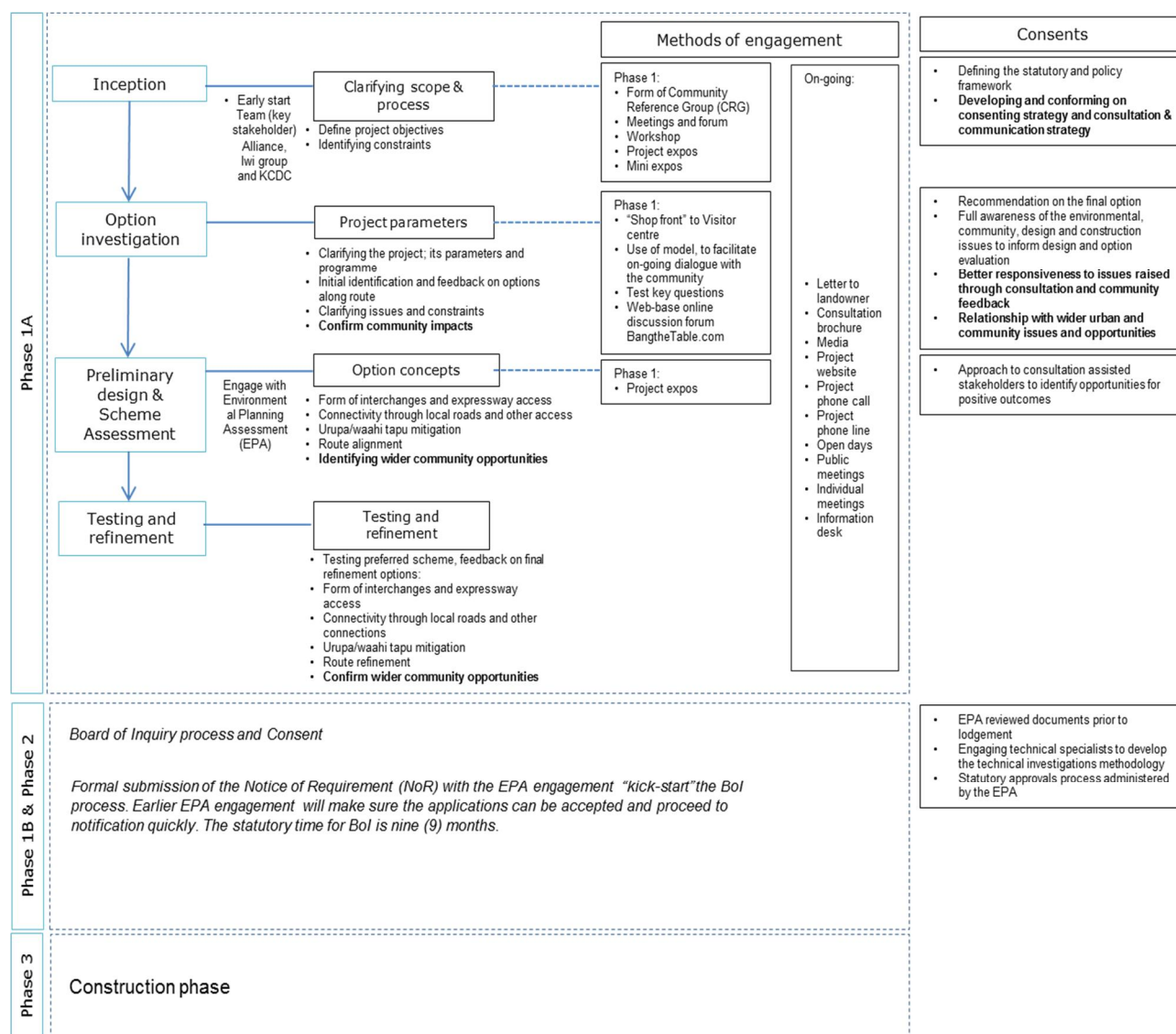


Figure 1 shows the progressive process of the engagement of the New Zealand expressway project.

In the process of Preliminary design and Scheme assessment, concentrated periods of consultation occurred. At this stage, wider community opportunities were identified. Throughout the process on-going opportunities of the community input or queries were recorded. At this stage, project expos acted as a platform to present the concept of the expressway and to obtain feedback and identify further issues. The final option for the expressway and refined detail were communicated to stakeholders. Issues such as cycleway and pedestrian linkages, local road, old state highway were issues requiring input from the community.

The earlier engagement period ran for 10 weeks. Letters to stakeholders were sent to potentially affected property owners, followed by a consultation brochure with a feedback form to ask the effected stakeholders preferred route options. Information of the expressway could be viewed through a project website, open days, information desks and also through a project phone line. Public meetings and meetings with individuals within the community were held. More than 200 engagement sessions were conducted between 2010 until 2012 on the first phase of engagement session.

#### **4.2.2 Initial stage in Malaysia mass rapid transit system**

The first stage of the engagement programme for the Malaysian MRT system was to educate the community and other external stakeholders. The agency developed connections with the community through a programme that they formed at the beginning. This included with campaigns and events. This promoted awareness about the MRT project and educated the public about the need for mass rapid transit system. One of the campaign that was conducted was the project's logo competition and "I Love MRT" best slogan. The agency also provided updates on the progress of the construction of this first phase line through social media. The project owner approached public schools within the Klang Valley vicinity, which helped to develop awareness among school students on the importance of the project.

The project adopted a standard practice that any community living or operating a business adjacent to the railway alignment and potentially impacted by the construction of the railway project must be kept informed of construction activities. Such engagement ranged from town-hall gathering to one-on-one meetings. Communities could also raise issues and give feedback. During the period under review, more than 60 engagement sessions were organised with residents, resident associations, business people, traders and other group. The most common types of feedback include concern over noise generated from construction work, traffic congestion and concern over living close to the railway alignment. Many stakeholders also expressed the hope that the railway project was completed as soon possible so that inconvenience can be minimised. A stakeholder could lodge a report regarding their properties through free phone line or visit a project information centre located at the corporation headquarters, or visit two information kiosks within the project area.

Engagement sessions were conducted throughout the early project stages and, from the interviews with the management team and the stakeholders, which led to seventy per cent of the affected residents and business owners supporting the project. An extensive and continuous effort was conducted to promote the project to the public during the early start of the project. Campaigns and programmes taking place at the early phase of the planning project advocated reasons on the needs of urban rail system in the city. Public attention was focussed on finding solutions for land issues including novel ideas of allowing privately owned land to coexist with the project by way of a Mutual Agreement between the landowner and the corporation. Almost all owners of shops and houses along Jalan Sultan retained ownership of their properties while allowing the project tunnel to be built underneath. In an effort to keep stakeholders updated with latest project work plans and works to be carried out, regular engagement sessions were initiated to ensure timely and effective dissemination of project and construction-related information to

the residents living within the construction worksites vicinity. The process of the engagement followed is shown in Figure 2.

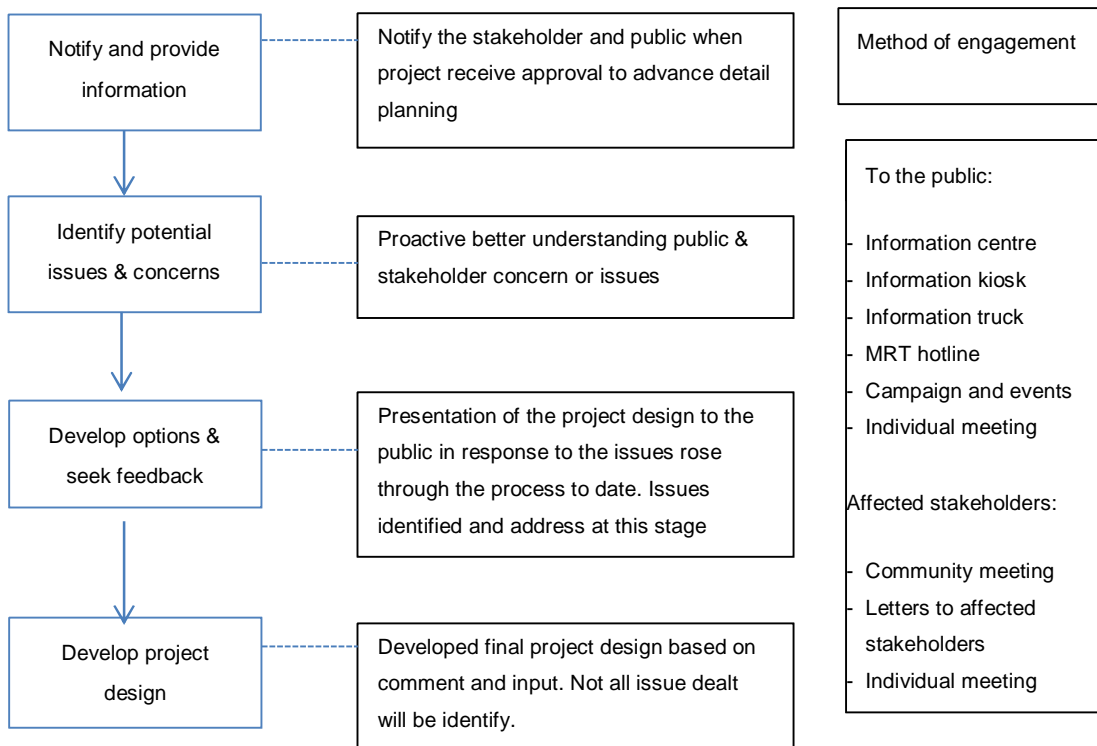


Figure 2: Process of initial preparation and alignment of Klang Valley MRT project

### 4.3 Three focus areas for engagement success

#### *Closely engaging the public*

The need for closely engaging with the public is so that the public develops an awareness of the project and the client obtains feedback and opinions from the public about the project. Stakeholders want to be part of the project. It is essential that their opinions are sought and they are listened to and their ideas are collated and integrated into the project process. In both cases stakeholders were encouraged to provide their opinions. Without adequate consultation, even if stakeholders are not against the project, they can become unhappy with the way the project is being implemented without due consideration for the well-being of people directly affected by the project.

#### *Transparency of information*

In term of transparency of the information, both cases provided information. The New Zealand expressway case study showed more transparency of information then Klang Valley mass rapid transit case study. For example, expressway has a central website accessible to the public consisting of a large amount of information regarding the project and the stakeholders. Important information was able to retrieved from the website such as stakeholders entities (agency, organisation, individual landowners,

traders etc.) and who was affected (directly or indirectly) with the project. In the mass rapid transit project information were not easily accessible. Information had to be retrieved from informal channels such as blogs and online forums, where official verification of the information is more difficult. Both expressway and mass rapid transit have information on the community perspective but only on the expressway were the community comments analysed through a comprehensive community report which was accessible through the website for expressway. This report showed the analyses of feedback such as what was the interest, their insights and opinion on the project and stakeholder list. In Malaysia, although the public community were able to provide comment and feedback, the report analysis was too generic. For example, detail information such as compilation of what are their interests, feedback and stakeholder list were not accessible. Information from the expressway case study was more transparent and accessible to the public than mass rapid transit case study.

#### *Improving stakeholder understanding of the design concept*

Socialising design concepts with stakeholders through engagement processes improves mutual understanding of needs. In the mass rapid transit case study, the engagement stage could be improved during the design concept stage of the project. The project authority should offer details of the plans, especially where land acquisitions are likely. The expressway three design options were all presented to the stakeholders. The stakeholder could help make a decision on which path the expressway should follow based on the consultation process and feedback.

## **5. Conclusions**

Engaging stakeholders in large-scale projects can be a complicated and lengthy process. Infrastructure projects, which involve many stakeholders, must have a developed engagement process. The engagement process should start at the early preparation stage. Ineffective stakeholder engagement will cause problems for the project. The benefit of understanding the stakeholders leads to better outcomes as their needs and interest can be used to develop solutions to project challenges. This paper has focused on how to improve an engagement process in a large infrastructure project through considering three simple factors in the engagement process – engage closely; improve transparency and improve stakeholder understanding of the design concepts. By developing mechanisms for improving these three features, early stakeholder engagement will lead to better long-term project outcomes.

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# Development of a Collaborative Briefing Approach to Support Stakeholder Engagement in Construction Briefing

## Abstract

*Jacky K.H. Chung<sup>1\*</sup> and Kua Harn Wei<sup>2</sup>*

Construction briefing is the process that a project client either formally or informally informs the designer of his or her requirements of a project at the pre-design stage. Literature shows that construction briefing is recognised as one of the most important processes in project management and therefore, it is crucial to get the brief right at the beginning so as to ensure effective delivery of the project in time and within budget. A previous study introduced the concept framework named “Collaborative Briefing Approach” (CBA) which was designed to empower the traditionally mobilised briefing team to work collaboratively with a large group of multi-disciplinary stakeholders as an integrated briefing team in the form of a virtual organisation through a shared digital workspace created on a computer network. This paper presents the findings of the said study and describes an on-going study designed to investigate the extent to which the use of CBA approach can improve the effectiveness and efficiency as well as the quality of outputs of the briefing process. This study adopts two research methods including controlled experimental study and action research and their details are presented in the paper. These two studies are the pioneer research studies that introduce a shared digital workspace to enable all members to work together remotely and asynchronously in the briefing process. They will demonstrate a new knowledge on how to apply collaboration technology to improve the process and output quality of construction briefing in a practical manner.

**Keywords:** Construction Briefing, Stakeholders, Collaboration, Collaborative Briefing Approach

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# **Development of a Collaborative Briefing Approach to Support Stakeholder Engagement in Construction Briefing**

## **1 Introduction**

Briefing is the first step in design process that a client either formally or informally informs others of his or her needs, aspirations and desires of a project (O'Reilly, 1987; CIB, 1997; Hershberger, 1999). Briefing can be considered to be synonymous with 'Architectural Programming' used in North America (Kelly and Duerk, 2002) and 'Scope Management' used in Australia (Peakman, 2008). These terms essentially describe the same activity and they are interchangeable. It is also described as a process of identifying and analysing the needs, aims and constraints of the client and the relevant parties, in formulating the design problem (ISO, 1994, BSI, 1995).

Briefing is recognised as one of the most important processes in project management. At the pre-design stage, briefing investigates the nature of design problem by helping clients to define, translate, communicate and present their needs and wants into a set of written project requirements in form of specific technical characteristics, functional performance criteria and quality standards. These requirements, which are the root of briefing, act as a basis for approaching designers (O'Reilly, 1987, Barrett and Hudson, 1996, Barrett et al., 1999; Bowen et al., 1999). At the design stage, these requirements provide guidelines on examining the developed design options so as to determine the optimal one, according to the defined design problem. At the post-design stage, these requirements help clients to review the selected design options during the construction and operation phases (Kelly and Duerk, 2002). As explained above, significant resources are committed in briefing and therefore, it is crucial to get the brief right at the beginning so as to ensure the effective delivery of the project in time and within budget (MacPherson et al., 1992; Latham, 1994; Newman, 1996). As a result, clients are strongly recommended to define and examine their needs in terms of project requirements, before and during briefing (HMSO, 1964; HMSO, 1994 and CIB, 1997).

This paper aims to introduce the Collaborative Briefing Approach and discuss its potential of improving the value of project briefing by capturing the inputs from stakeholders through collaboration technology. It begins to discuss the importance of stakeholder engagement in construction briefing and then introduces the concept of Collaborative Briefing Approach. It follows by a discussion about the associated research studies on this topic

## 2 Stakeholder engagement in construction briefing

### 2.1 Stakeholder theory and stakeholders

Stakeholder theory was originated from stakeholder concept, which divided major stakeholders into four groups including shareholders, employees, customers, and the general public in General Electric Company in 1929 (Mishra, 2013). This stakeholder concept was fully articulated by Freeman, who drew on various literatures including corporate planning, systems theory, and corporate social responsibility to develop the concept into a theory (Freeman, 1984). The theory identifies and models the groups which are stakeholders of a corporation, and both describes and recommends methods by which management can give due regard to the interests of those groups (Donaldson and Preston, 1995). It suggests that a modern organisation has relationships with many constituent groups but traditional management theories cannot address the “shifts” in business environment induced by the impacts from internal stakeholders and external stakeholders. Consequently, the theory argues that organisations should take into account all of those groups and individuals that can affect, or are affected by, the accomplishment of the business enterprise instead of limited to shareholders only (Freeman, 1984). Based on the said theory, a UK example of the key stakeholders in a redevelopment project is presented in Figure 1.

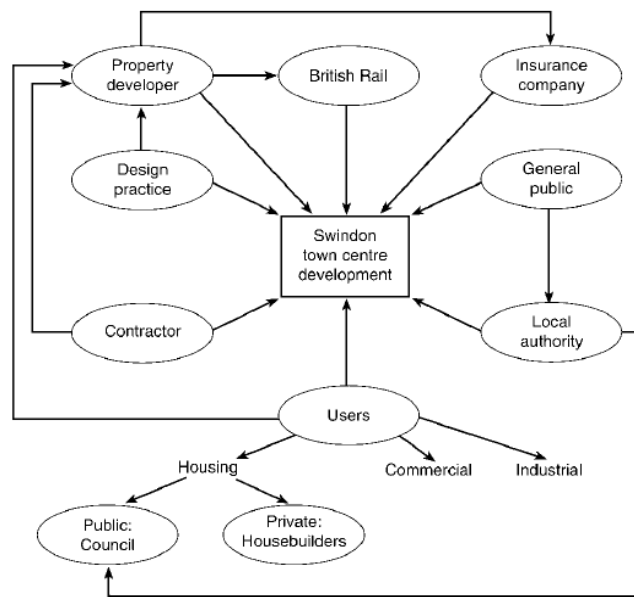


Figure 1 : Key stakeholders in the Swindon redevelopment project (Newcombe, 2003)

The above sample indicates the relationships between various groups and individuals in a single analytical framework. Each oval representing a group of stakeholders. The central square, which represents the project, is surrounded by a number of other ovals with directional arrows toward the square as well as ovals (Freeman, 1984).

## 2.2 Stakeholder theory and construction briefing

As described by MacPherson et al. (1992), briefing develops an interface between the project design process and the social-political environment in construction. With reference to the stakeholder theory, briefing should involve a large number of stakeholders other than the project design team members and they include builders, suppliers, operators, end-users, government bodies, professional representatives and residents as shown in Figure 2, which is in line with the concepts applied in the IFSIUER model and its variance proposed by Kua (2007, 2016).

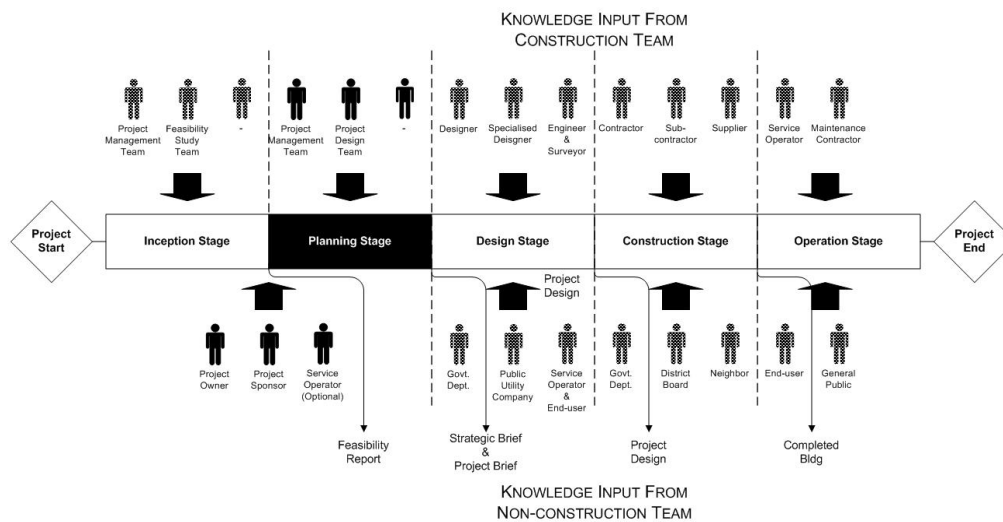


Figure 2 : Stakeholder knowledge input to briefing

Moreover, briefing requires a full spectrum of knowledge and skills involved in various construction stages to make the best decisions in the briefing process (MacPherson et al., 1992; Kelly and Duerk, 2002). However, stakeholders own a substantial amount of important information and tacit knowledge, which are kept hidden, without sharing across projects due to the 'wall syndrome' (Kamara et al., 2002). As shown in Figure 2, they add value to briefing and their early participation makes the following general contribution to the briefing process (Kelly and Duerk, 2002).

- provide technical knowledge that helps to increase the amount of available project information
- provide professional advice to identify the potential problems
- provide the latest technology to promote creativity and innovative solutions

## 2.3 The research opportunity

In recent years, the role and importance of these stakeholders have been recognised in the modern management concepts such as partnering, supply chain management and lean construction etc. For example, the early involvement of operators in private participated public projects helps enables designers to have more information about the operation requirements to anticipate potential problem areas and make better design. In construction, clients should involve stakeholder inputs so as to add value to briefing (HMSO, 1994) but literature shows that their participation is very limited in

construction briefing. For example, construction briefing is usually limited to a small group of key stakeholders including project owners, sponsors and designers. It is because some project owners may fear that more stakeholder involvement could lead to a flood of “wish lists” which is challenging to accommodate. Moreover, it would be expensive and time consuming to organise large stakeholder meetings and to resolve all stakeholder conflicts, in turn delaying the design progress. As a result, the value of briefing products would be sub-optimal because the valuable inputs from these stakeholders have been locked (Shen and Chung, 2006).

It is assumed that the overall values of briefs can be significantly improved if we can unlock, capture and manage the stakeholder inputs in a more efficient and effective way. Since collaboration technology which enables people in working together in ‘virtual space’ is an effective tool in improving team communication and collaboration, authors suggest that there is plenty of room for using collaboration technology to conduct construction briefing in a virtual environment in pursuit of greater involvement of stakeholders.

### **3 Collaborative Briefing Approach**

'Collaborative Briefing Approach' (CBA) is designed to empower the traditionally mobilised briefing team to work collaboratively with a large group of multi-disciplinary stakeholders as an integrated briefing team in the form of a virtual organisation through a shared digital workspace created on a computer network (Chung et al., 2009 and Chung, 2010). The CBA approach introduces a shared digital workspace that serves as a collaborative platform and enables all members to work together remotely and asynchronously so as to achieve greater stakeholder participation in briefing. Since stakeholders contribute in bringing professional knowledge, experience and creativity to briefing, greater stakeholder participation will increase their inputs and result in more fruitful briefing outputs.

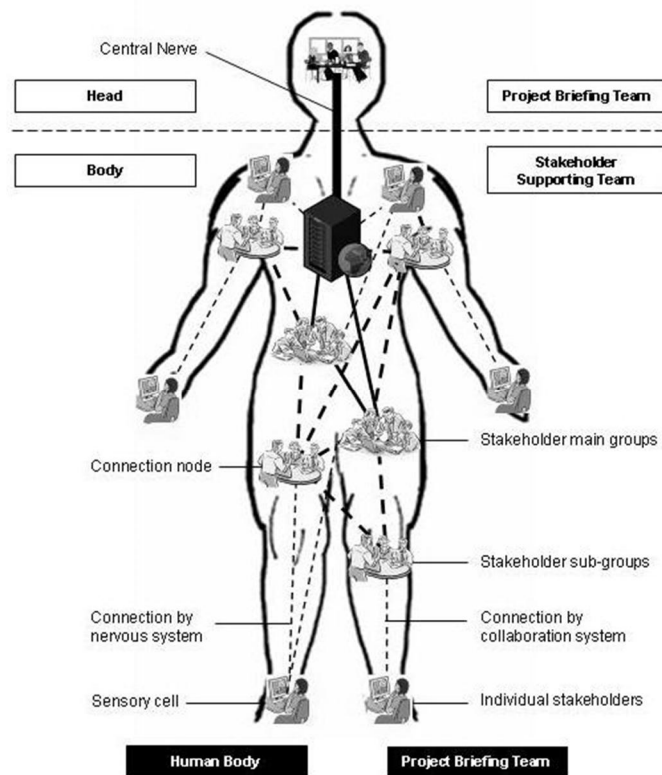


Figure 3 : A virtual organisation in briefing (Chung et al., 2009)

As shown in Figure 3 there are significant similarities in the organisation structure and the communication hierarchy between them. For example, team members (cells) are working closely with in-house colleagues to form a sub-group (tissue) in representing their organisations (e.g. contractors). Various sub-groups are working together to form a main group (organ) in representing their professionals (e.g. engineering consultant group). Several main groups combine to form a functional unit (system) in representing their roles (e.g. construction team). Lastly, various functional units are working together as a virtual organisation (human body) in representing a whole team in briefing (e.g. briefing team). Drawing parallels with the concept of a biological neural network that connects cells, tissues, organs and systems together with brains in humans; a computer-based collaborating system is proposed to manage the discussion among team members within this virtual organisation in briefing. The above analogy is only for indication of the holistic interactions rather than for over-simplification of briefing needs (Chung et al., 2009).



## 4 An on-going study

### 4.1 Phase 1 study

A research study titled “Improving megaproject briefing through enhanced collaboration with ICT” was conducted in 2010 to explore the feasibility of applying collaboration technology to improve the briefing output by capturing stakeholder values through the enhanced collaboration between clients and stakeholders in the briefing process (Chung et al., 2008, Chung et al., 2009, Chung, 2010, and Chung, 2015). Under this study, a comprehensive survey investigating and comparing the strengths and weaknesses of common briefing practice in the Hong Kong construction industry was completed and based on which, a theoretical foundation for the research was established. In addition, a new briefing approach named 'Collaborative Briefing Approach' has been developed based on Stakeholder Theory. Moreover, an 'Integrated Collaborative Briefing Methodology' (INTERCOM) was also developed to translate the CBA approach into a set of actionable methods and job plans for practical use and a pictorial summary is given in the following figure.

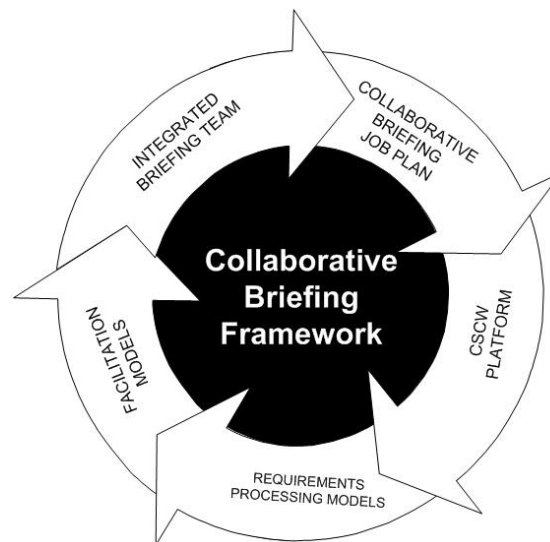


Figure 4 : *Key Elements of the collaborative briefing framework*

As shown in Figure 4, the INTERCOM comprises of five components: (i) a value based briefing methodology, (ii) a collaborative briefing job plan, (iii) an integrated briefing team, (iv) a collaborative briefing platform, and (v) facilitation service. The first four components were developed and validated by a group of well experienced multi-disciplinary industry practitioners. The fifth component merits a separate research and development exercise. Research findings reveal that the concept of collaborative briefing approach and the design of the INTERCOM are well supported by the practitioners. In addition, it is concluded that INTERCOM would contribute to improve the briefing process by facilitating team management, enhancing requirement definition and promoting consensus building. It also improves requirement comprehensiveness, decision transparency, decision reliability, and decision satisfaction, as well as the value and quantity of the requirements specified in the brief (Chung, 2010). This study comes to the conclusion that the concept of collaborative briefing approach and the design of the INTERCOM are well supported by the practitioners. In addition, INTERCOM would contribute to

improve the briefing process by facilitating team management, enhancing requirement definition and promoting consensus building. It also improves requirement comprehensiveness, decision transparency, decision reliability, and decision satisfaction, as well as the value and quantity of the requirements specified in the brief (Chung, 2010).

## 4.2 Phase 2 study

In order to extend the research potential of the phase 1 study, a new research to study the CBA approach from a new perspective through experimental studies and action research and thereby investigate the extent to which we can apply collaboration technology for the purpose of improving briefing output. This phase 2 study aims to investigate the extent to which we can apply collaboration technology to improve the briefing output by capturing stakeholder values through the enhanced collaboration between clients and stakeholders in the briefing process. Thus, the objectives of this study are to:

- investigate the extent to which the use of CBA approach can improve the effectiveness and efficiency in the processes of briefing in construction projects;
- investigate the extent to which the use of CBA approach can improve the quality of outputs of briefing; and
- identify critical success factors that lead to effective implementation of CBA approach in briefing.

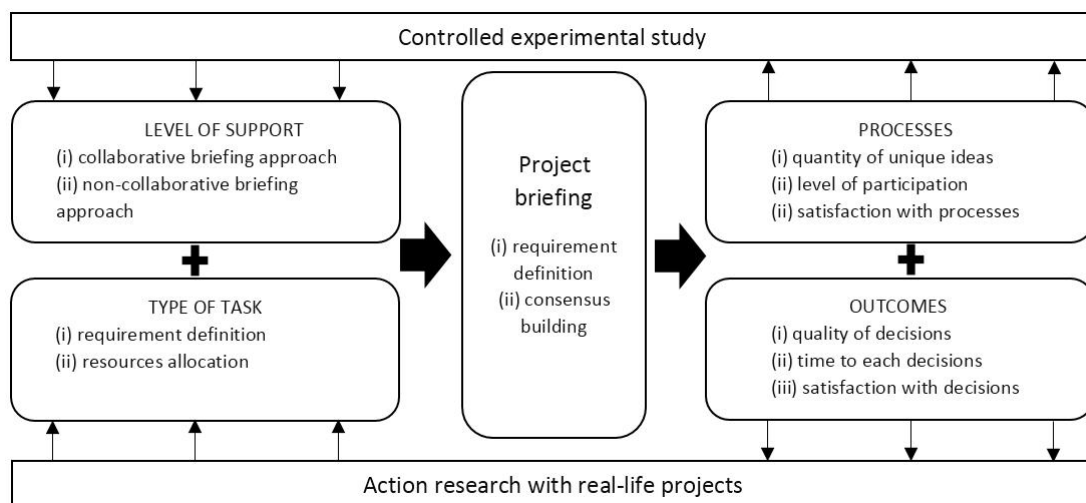


Figure 5 : *Proposed research framework*

Figure 5 illustrates the framework for the proposed research. In order to achieve the research objectives, two research methods, namely (i) controlled experimental study and (ii) action research will be adopted and the details of which are summarised in Table 1.

*Table 1 - Summary of research methods*

<b>Method</b>	<b>Description</b>
Controlled experimental study	<p>A controlled experimental study with 2 x 2 factorial measures will be adopted, under which independent variables are expected to be controlled and thereby the consequent changes in the dependent variables can be observed. In addition, experimental variables can be isolated more easily and their impact can be evaluated more effectively than other methods. In the proposed research, there are two independent variables, namely (i) level of support, and (ii) type of task.</p> <ul style="list-style-type: none"> <li>• The support variable has two levels: CBA approach and non-CBA approach.</li> <li>• The task variable also has two levels: requirement definition and resources allocation.</li> </ul> <p>Statistical test and analysis of variance will be used to examine the likelihood that the means of the experimental and control groups are derived from a single-parent population and can be compared for possible differences.</p>
Action research	<p>Real-life construction projects will be conducted to examine the real effect and impact on a number of key issues including the levels of task difficulty and user satisfaction in the research process. It is characterised by involving researchers as part of the situation under exploration. The applicant will play the role of a facilitator to design and deliver the project briefing exercise for these selected projects. Moreover, focus group will be used a supplementary instrument to facilitate the research team to obtain valuable views and insights from participants of the exercises. During focus group meetings, the research team members can ask and adapt questions as necessary, ensure that questions and responses are properly understood by repeating or rephrasing them, and pick up non-verbal cues from the respondents.</p>

### **4.3 Research contributions**

The proposed research is one of the pioneer research studies in exploring the concept of team collaboration in construction briefing. It aims to introduce a shared digital workspace that serves as a collaborative platform and enables all members to work together remotely and asynchronously so as to achieve greater stakeholder participation. Following the success of the previous study on CBA approach described before, the proposed research will study the approach from a new perspective by using the methods of experimental studies and action research. It is anticipated that this will lead to new knowledge on the real effectiveness of adopting the CBA approach in improving the process and the output quality of construction briefing in a practical manner. Such knowledge will help to justify the real benefits of the approach and thus, determine a “benefit to cost ratio” so as to identify the most suitable project type for using CBA approach. Moreover, a set of critical success factors contributing to the implementation of CBA approach in briefing will be identified in the research. These factors will help to increase our understanding of some hidden factors such as group dynamics, and facilitation, contractual barriers and politics etc. that emerge in real life application. In summary, the proposed research will strengthen the connection between the knowledge of construction briefing and the domain of team collaboration through the “CBA approach”.

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# Contradictions of interests in early phase of real estate projects – What adds value for owners and users?

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## Abstract

In the last decades, Norwegian real estate projects have traditionally focused on cost minimization rather than value optimization. The main intention of the research project “OSCAR – value for Owners and Users of buildings” is to develop competences, methods and analysis tools that makes it possible to optimize the design that creates value for owners and users throughout the buildings’ lifetime. This paper aims to elucidate what adds value for owners and users as well as looking at what are the main contradictions of interests in early phase planning of buildings. The research is approached by a literature review and a questionnaire survey among a wide range of stakeholders (N = 799) in the Norwegian building Industry. The survey focus on the four dimensions of sustainability, namely social, economic, environmental and physical aspects of the building. In this paper, we focus on the economic and social value aspects, and look at how these contribute to value creation for owners and users of buildings. The literature points towards need for increased competence in value management and new co-creative collaborative working models as a continuously part of the building process. We suggest using a structured network role to better understand and safeguard the owner, user and FM needs, and to improve the users’ influence on the decision process in early phase of constructions projects. We believe this is a successful way of finding innovative designs and technical solutions. Exploratory principal component analysis (PCA) of the responses gave many interesting findings. The owners and users have significantly different views concerning financial issues and efficient operation of buildings in the use phase. These findings are topics for further research.

**Keywords:** Early phase involvement, owner, user and Facilities Management involvement, co-creation models, value management, building process

# 1. Introduction

This paper aims at elucidating contradictions of interests between owners and users of buildings. Equally, it examines how co-creation and co-collaboration models can be useful to ensure better building quality and usability, and to increase the owners and users' involvement in the early-phase of real estate projects.

This paper includes the main findings of a survey conducted among a broad range of stakeholders within the construction industry in Norway. Norwegian real estate projects during the last decades have had more focus on cost minimizing than value optimization. The main ambition of the survey is to find out what in the early phase planning process and what in buildings add value for owners and users. The survey is a part of a Norwegian research project OSCAR.<sup>1</sup> We discuss how user involvement is handled and how collaboration models can improve the quality of buildings and add value for both owners and users.

In order to address this general query, this paper search to answer the following questions:

- What contradictions of interests are there among owners and users in an early phase of real estate projects?
- How is user involvement in the early phase of real estate projects handled today?
- How can co-creation and co-collaboration improve the adding value processes in early phase of real estate projects and solve some of the contradictions?

The first question is addressed through both the literature review and by the survey (examined in the theoretical framework section and the findings section respectively). Question 2 is covered by the survey and examined in the findings section. Question 3 is discussed according to a theoretical point of view and from experiences in practise.

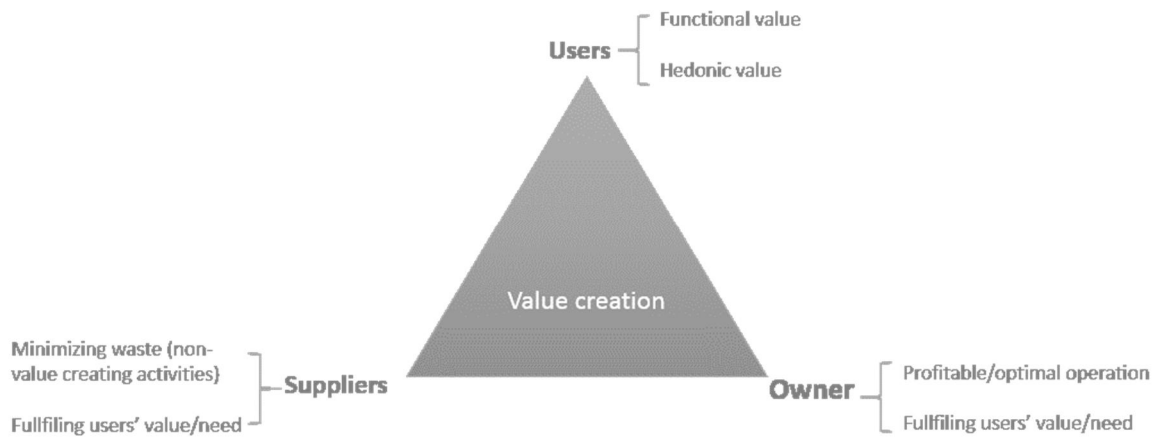
## 2. Theoretical framework – How do buildings add value?

A building creates economic and social values in many ways. For an owner the building creates a positive or negative cash flow. For the user the building works both as a social arena and a place for production and value creation. Depending on the personal and organizational values we talk about, which values are important to the core business, and how can the building be supportive to the organizations' values and help them to achieve their goals? For the actors involved in the construction process focus rather on the value creation than what adds value for the user. The concept of *value* is complex and varies depending on the perspectives taken. Value is exceptionally difficult to measure. Drevland and Lohne (2015) talk about nine tenets of the nature of value while Haddadi et al (2015) explores the concept of value in different context and points out the need of change of value perspective in FM and Real Estate. They present a simplified

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<sup>1</sup> OSCAR – Norwegian research project "Value for User and Owners of Buildings" ([www.oscarvalue.no](http://www.oscarvalue.no))

image of the involved actors but an easy way to understand the drivers and ambitions that the actors are striving to reach in order to create value.



*Figure 1 Real estate projects main roles and their values to to be fulfilled in order to enhance value creation (Source: Haddadi et al, 2015).*

A more sophisticated model (CRISP in Spencer and Winch, 2002) shows the complexity of stakeholders involved in the whole building process. This model categorizes the factors according to different key performance criteria and points out that the stakeholder's view point, power and value systems influence the decisions. The stakeholder's viewpoints and values has a tremendous effect on the product and the users and the way they can create value in the operational phase.

## 2.1 How buildings add value for owners and users?

A building adds value when it facilitates value creation for the user organizations during the building's lifetime. Therefore, the building should function according to its appropriated need Based upon our own experience we find that owners and users focus on various issues and aspects of a building's performance, presented in Table 1.

*Table 1: What properties and factors are of importance for the buildings' value creation (authors' experience)?*

<i>Sustainability</i>	<i>Economic issues</i>	<i>Social issues</i>	<i>Environmental issues</i>	<i>Physical issues</i>
<i>Owner</i>	<i>Investment cost LCC and FM costs Profit</i>	<i>Tenant relationship Market</i>	<i>Energy, water and waste</i>	<i>Operational and Maintenance Total adaptability</i>
<i>User</i>	<i>Rental cost FM costs</i>	<i>Facilities services Market</i>	<i>Indoor environment Profile and branding</i>	<i>Location Flexibility of space</i>



In this paper, we focus on the *economic and social dimension*. We look at how these factors are affecting the buildings' value creation for owners and users, further explored in the survey partly presented in section 3.

## 2.2 Stakeholder involvement in early phase planning

Stakeholders in a real estate project can be both internal and external. Who are involved in the decision process and who are the stakeholders in the surrounding environment that are affected by a new building? Since the involvement process can be complex, it requires leadership and facilitation skills. Sometimes important groups are excluded due to lack of knowledge or experience with new technology, or because they not necessarily know or are not able to articulate what they want. The management of the process is therefore of huge importance (Heitel et al., 2015; Storvang and Clarke, 2014). Jensen and Maslesa (2015) developed a tool suitable for big projects for systematically involvement of stakeholders in the project. This is an interesting tool that is relevant to be tested in the OSCAR project. Artto et al. (2015) maintain that increased involvement of the stakeholders that actually are users of the building has vital importance for the usability. They suggest to initiate a stakeholder network in early phase of the building and to start a value management process early due to the stakeholder's different values and attitudes. This will require a change of the building and work process of particularly the early planning and design phase, but also challenge the traditional way of executing real estate project. Such a network can easily fill the "Structural Role" as suggested in the CRISP model (Spencer and Winch, 2002)

The researchers discusses user involvement widely and conclude with that this is important but very complexed. Some good examples from the Norwegian context of user involvement that have resulted in buildings with high usability is the Power house of Kjørbo in Sandvika<sup>2</sup>, and the Sparebank 1 building<sup>3</sup>, a bank quarter in Trondheim. The owners state that they succeeded because of their clear and ambitious goal, namely involvement of a broad competence in the design phase, hereunder users and facilities managers (Meistad, 2015).

A view from researchers and practitioners involved in construction of Norwegian hospitals is that the tradition has been broad user involvement from both the hospital units and patient groups. The trend is now going towards a more specialised involvement of the clinics and hospital units rather than patient groups. In the hearing process, the patient groups involved have possibility to respond with views and statements as they are represented by their patient organizations (Sintef Helse<sup>4</sup>). The Norwegian Health authority<sup>5</sup> developed for early phase planning that describes the processes and decision gates of the early phase in hospital projects. Several large hospital projects have used

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<sup>2</sup> Kjørbo Powerhouse (<http://www.powerhouse.no/en/prosjekter/kjorbo/>)

<sup>3</sup> Sparebank 1 (<http://www.arkitektur.no/sparebank-1-smn?tid=158202>)

<sup>4</sup> Dialogue with senior researcher Marthe Lauvsnes, Sintef Helse Nov 30, 2015

<sup>5</sup> The Norwegian Health authority ([www.helsedirektoratet.no](http://www.helsedirektoratet.no))

this guideline but it does not say anything about the involvement of user groups. In a revised version that is to come, user involvement will be an important issue, we hope.

### **2.3 Co-creation and collaborative models**

Co-creation is a popular concept of innovative thinking, more precisely how business and clients can cooperate to develop new products that can create mutual value. This concept has been recognized especially when developing new products. The mind-set however, is highly relevant for real estate projects today. In the construction context, we do not only promote co-creation in order to obtain a sustainable building with good use qualities. We do believe that co-creation processes have a huge potential to increase the understanding of the users' needs and owners concerns. It has successfully been used to processing involvement of several stakeholders and necessary competences. Frow et al. (2015) presents a framework for a structural approach when doing co-creation processes that includes diagnosing needs, designing solutions, organizing the process, managing conflicts and implementation. The framework aims to facilitate the questions: What are the critical resources? What are the roles in the joint activities? The need for a more collaborative approach in order to achieve a sustainable practise with high a degree of user satisfaction is also emphasised by others (Meistad, 2015, Støre-Valen et al., 2014, Gemser and Perks, 2015). This is highly relevant in the early design phase.

## **3. Research approach and methodology**

This research is based on a comprehensive literature review and a national online survey among a wide range of stakeholders (N=799) in the Norwegian building industry. The survey was conducted from May to September 2015.

The literature search was based on search in databases like Google scholar, Iconda and Scopus with the search words like "Value management", "Stakeholder involvement" and "Early phase planning". The literature review looked for obstacles and barriers concerning which factors that add value for various owners and end-users of buildings. The literature review also examined what the literature says about involvement of stakeholders in the early phase of real estate projects.

The aim of the national survey was to identify which aspects of a building provide value for owners and users. The questions in the survey are based on extensive literature studies. The questions and the questionnaire was pretested on various stakeholder groups before the final version of the survey was sent to professional associations that organize stakeholders in private enterprises, public administrations and non-profit organisations involved in planning, construction, and provision of parts, services, and owners and users of real estate. The survey measures four dimensions of sustainability, namely the economic, social, environmental and physical dimensions. The analysis presented in this paper focus on the two aspects: namely *economic and social aspects*. The respondents were asked to score the statements from one to four (1 = none weight, 2 = some weight, 3 = strong emphasis and 4 = very strong emphasis).

The respondents' answers have been analysed through descriptive statistics and exploratory principal component analysis (PCA) with IBM Statistics SPSS version 22. The general purpose of exploratory PCA and other kinds of exploratory factor analysis is to summarise the information in a number of questions (variables or items) into fewer (latent) composite dimensions with the smallest possible loss of information to identify the fundamental or theoretical constructs underlying the survey questions (Hair et al., 1998:95).

In PCA and other kinds of factor analysis, it is common to rotate the matrix in order to achieve a simpler and more meaningful solution. The rotation is a mathematical manipulation of the factor axis. VARIMAX rotation (orthogonal rotation) often gives a clear separation of the factors (Hair et al., 1998:89-90, 107-111). Our exploratory PCA is based on VARIMAX rotation. Bartlett's test of sphericity and Kaiser-Meyer-Olkin's (KMO) measure of Sampling Adequacy are two commonly statistical tests used for the data's appropriateness. KMO for our data are 0.665 or better, and the p-value for Bartlett's test is 0.000 for all of the categories.

The respondents answer from an owner or a user perspective. They also answered from whether or not they had been involved in early phase planning of real estate projects. The aim of our statistical analysis is to elucidate whether owners, users and those who have or have not been involved in early phase development of buildings answer different on questions concerning the economic and social dimensions.

## **4. Results from the Statistical analysis**

In this section, we first present the findings from the descriptive statistics of the respondents and thereafter the findings from the exploratory PCA of the answers about the questions concerning the economic and the social dimension from respondents with an owner or user perspective. We distinguish between those respondents who have been or not have been involved in early phase planning of building projects. Interestingly enough, both those with an owner and user's viewpoints indicate that financial issues and cost efficient operational services has most value. More details will be discussed in the forthcoming section.

Table 2 shows the number of respondents distributed on their employment role, from an owner and user perspective as well as their role in the early phase development of real estate projects.

Table 2: The respondents' perspectives, employer and roles in early phase development

	Owner				User			
	Early phase - development				Early phase – development			
	No		Yes		No		Yes	
	Count	Row N %	Count	Row N %	Count	Row N %	Count	Row N %
Respondents' Public sector employer owned enterprise	36	54.5%	30	45.5%	5	45.5%	6	54.5%
Privately owned enterprise	116	41.4%	164	58.6%	76	50.0%	76	50.0%
Public authority	40	58.8%	28	41.2%	26	63.4%	15	36.6%
Municipality or county municipality	73	52.9%	65	47.1%	15	65.2%	8	34.8%
Total	265	48.0%	287	52.0%	122	53.7%	105	46.3%

Among the 779 respondents in the survey who answered the questions about their employer and perspective 552 or 70.9 percent answered the survey with an owner perspective, while 227 or 29.1 percent answered with a user perspective. Among the owners 52.0 percent have been involved in the early phase of real estate projects. 46.3 percent of the 227 respondents with a user perspective have been involved in the early phase. Table 2 also provide a detailed overview of the respondents' employers. 77 (10 percent) of the respondents are employed by enterprises owned by the public sector. 432 (56 percent) respondents are employed by private enterprises. A public authority employs 109 respondents (14 percent). A municipality or county municipality employs 161 respondents (21 percent). Table 2 shows that a majority of the respondents employed by enterprises owned by the public sector have answered with an owner perspective. Table 2 also shows that the majority of respondents employed by private enterprises have answered with an owner perspective, and that a majority of these have been involved in early phase development. Table 2 even show that a majority of those employed by public authorities have answered with an owner perspective, but the majority of these have not been involved in early phase development. This is also the case for the respondents employed by municipalities or county municipalities.

Table 3 and 4 show the results of exploratory PCA of the respondents' answers of the questions concerning the economic and social dimensions.

Table 3: Main findings from PCA (VARIMAX rotation) of the data concerning the economic dimension (Cronbach's alpha > 0.6)

	<b>Component with items and factor loadings</b>	<b>Explained- total variance (%)</b>	<b>N</b>	<b>Reliability (Cronbach's Alpha)</b>
<i>Owner perspective – Respondents who have been involved in the early phase</i>	<b>#1: Cost efficient operations</b> Cost efficient cleaning (.749), Life cycle costs (.736), Energy costs (.663), Cost efficient services (.653), Total costs per workplace (.630), The building's economic life span (NPV of cash flow) (.564), The building's effect on core business (.554)	27.8	209	<b>0.788</b>
	<b>#2: Financial issues</b> Yield (.886), Economic risk (.839), Investment costs (.487), The building's market value in case of sale (.851)	25.2	207	<b>0.797</b>
<i>Owner perspective – Respondents who not have been involved in the early phase</i>	<b>#1: Cost efficient operation</b> Cost efficient cleaning (.808), Cost efficient services (.777), Energy costs (.715), Life cycle costs (.704), The building's economic life span (NPV cash flow) (.600), Total costs per workplace (.529)	28.5	181	<b>0.823</b>
	<b>#2: Financial issues</b> Yield (.906), The building's market value in case of sale (.873), Economic risk (financial and market risk) (.846)	26.9	185	<b>0.877</b>
<i>User perspective – Respondents who have been involved in the early phase</i>	<b>#1: Financial issues</b> Yield (.890), Economic risk (financial and market risk) (.887), The building's market value in case of sale (.799), Investment costs (.408)	24.6	58	<b>0.797</b>
	<b>#2: Cost efficient operations</b> Cost efficient cleaning (.820), Cost efficient services (.783), Total cost per workplace (.774), The building's effect on core business (.510), Life cycle costs (.433)	22.9	69	<b>0.751</b>
<i>User perspective – Respondents who not have been involved in the early phase</i>	<b>#1: Financial issues</b> The building's market value in case of sale (.833), The building's economic life span (NPV of cash flow) (.792), Yield (.680), Life cycle costs (.642)	25.0	51	<b>0.800</b>
	<b>#2: Cost efficient operations</b> Cost efficient services (.847), Cost efficient cleaning (.844), The building's effect on core business (.653), Total cost per workplace (.550)	23.2	65	<b>0.754</b>

Table 3 shows that PCA of the answers from the respondents with an owner perspective who had been involved in early phase came out with two reliable components, namely the first, which we denote; *cost efficient operations*, and the second one, which we denote, *financial issues*.

PCA of data from the respondents with owner perspective who not had been involved in early phase development gave similar results This was also the case for respondents who answered with a user perspective that had not been involved in the early phase. The Bartlett's test of sphericity indicates sufficient correlation between the questions; the constructs derived through PCA are thus acceptable with regard to both sampling adequacy and reliability.

A tentative conclusion concerning the economic dimension is that respondents who answered the survey with owner and user perspectives have different opinions concerning the economic dimension. The findings are somewhat contra-intuitive, because those who answered with an owner perspective seems to be more concerned with cost efficient operations than financial issues, while those who answered with a user perspective seems to be more concerned with the financials issues than cost efficient operations. These findings are actual for further studies.

Table 4: Main findings from PCA (VARIMAX rotation) of the data concerning the social dimension (Cronbach's alpha > 0.6)

Category of respondents	Component with items and factor loadings	Explained total variance (%)	N	Reliability (Cronbach's Alpha)
Owner perspective – Respondents who have been involved in the early phase	<b>#1: Workplaces facilitation social interaction</b> Workplaces facilitating flexible ways of working (.831), Promoting pride (the organization's cultural values) (.744), Areas facilitating formal and informal meetings (.728), Architectonic qualities (.637), Interior qualities promoting well-being and tidiness (.607), Facilities for physical exercises (.556), Individual management of sun screening, lights, temperature, etc. (.491)	27.8	196	<b>0.816</b>
	<b>#2: Safety and security</b> (protection against unwanted incidents) (.830), orientability (intuitive signs, etc.) (.798), user involvement (.514), corporate governance (.395)	21.2	218	<b>0.652</b>
Owner perspective – Respondents who not have been involved in the early phase	<b>#1 : Interior qualities promoting well-being and tidiness</b> (.740), Promoting pride (the organization's cultural values) (.699), Workplaces facilitating flexible ways of working (.693), Areas facilitating formal and informal meetings (.664), Safety and security (.661), Architectonic qualities (.615), User involvement (.601), individual management of sun screening, lights, temperature, etc. (.595), Facilities for physical exercises (.568), Corporate governance (.470)	41.2	182	<b>0.859</b>
User perspective – Respondents who have been	<b>#1: Workplaces facilitation social interaction</b> Workplaces facilitating flexible ways of working (.863), Areas facilitating formal and informal meetings (.823), User involvement (.603), Facilities	33.8	63	<b>0.858</b>

<i>involved in the early phase</i>	<i>for physical exercises (.602), promoting pride (the organization's cultural values) (.598), Safety and security (protection against unwanted incidents) (.598), Interior qualities promoting well-being and tidiness (.581), Individual management of sun screening, lights, temperature, etc. (.562)</i>			
<i>User perspective – Respondents who not have been involved in the early phase</i>	<b>#1: Workplaces facilitation social interaction</b> <i>Areas facilitating formal and informal meetings (.855), Workplaces facilitating flexible ways of working (.831), Interior qualities promoting well-being and tidiness (.782), Safety and security (protection against unwanted incidents) (.713), User involvement (.652), Promoting pride (the organization's cultural values) (.630), Facilities for physical exercises (.600), Safety and security (protection against unwanted incidents) (.598), Individual management of sun screening, lights, temperature, etc. (.583), Orientability (intuitive sign, etc.) (.551)</i>	40.2	66	<b>0.882</b>

Table 4 shows the factor loadings of the PCA of the answers for the social dimension. Even these data are found adequate for PCA. The respondents who answered the survey with an owner perspective who had participated in the early phase

The component that is found reliable (Cronbach's alpha > 0.8) for both respondents with owner and user perspective is denoted *workplaces facilitating social interaction*. The principal component analysis uncovered also a common factor with acceptable reliability for those respondents with owner perspective who not had been involved in the early phase, namely the entire battery of questions concerning the social dimension (11 items).

A tentative conclusion concerning the social dimension seems to be that most respondents in our study prefer well-designed workplaces that facilitate social interaction and various ways of working, no matter whether they have answered the questions with user or owner perspective and whether or not they have been involved in the early phase of building projects.

## 5. Discussion

### 5.1 Literature review

Based on the literature review, we maintain that the CRISP model is an interesting framework for processing complexity of the stakeholder involvement. The model shows how different stakeholder's interests, value systems and power influence the decisions and choice of solutions. In sum, these factors influence the final product, time and money spent as well as the final usability of the product. The CRISP model suggests using a structural role and sophisticated measures for the social impact to handle value management and user involvement. This is in line with other findings from the literature review, suggesting using broad network groups and broad competence involved in early phase (Spencer and Winch, 2002, Frow et al., 2015, Gemser and Perk, 2015).

The user roles have many opinions and the users do not always clearly understand what their needs are. Spencer and Winch (2002) assume that users may under-value design of the building as they find it difficult to communicate clearly their needs and vision for a building. They do not necessarily understand the value of a good building design; find it difficult to define their organizational values and to agree upon how to measure them (both tangible and intangible benefits). Spencer & Winch (2002) suggest a structured role to coordinate network groups, balancing power and help facilitating the creative process to find the best solutions for both client/owner and customer/user. A key question is what competence is necessary in the stakeholder groups in order to optimize the benefits of the involvement. We believe this will be a sensible approach concerning how to involve important stakeholders and to define the users' needs.

## 5.2 Survey

Our data show that the owners are more interested in user involvement in early phase development of buildings than the users themselves. This finding indicates that the process of being involved in early phase development gives both ownerships to the decisions and opportunities to influence the decisions. This finding corroborates the literature that show positive results from use of collaborative models for involving more stakeholders in early phase development (Frow et al., 2015, Meistad, 2015, Artto et al., 2015).

In the survey, we look at how different stakeholders perceive value in real estate projects. We discuss whether there are contradictions in values among owners and users. Surprisingly the owners think that user involvement is more important than the users do. It depends on who have responded to this question and what is their understanding of how user involvement can add value or not. The respondents' educational background, how they understood the questions and what they actually believe what choices and decisions they can influence in the early phase, are probably some explanations.

The literature also suggests co-creation models for involving users in early phase and design phase of a building project. There is a trend in the literature that recommend co-creation processes and collaborative working models in early phase. The Kjørbo project is one such a successful example on collaborative co-creation processes. This points towards a field of interest for further studies in the OSCAR project that is possible to explore in demonstration projects. Further research will be presented in the future.

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# Linking Activities During Construction to Inter-Organizational Value Co-Creation During Operations

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## Abstract

Value of construction projects is traditionally evaluated by the capability to use the facility for the planned purposes. In business premises, however, recent research highlights the creation of value in a project through establishing inter-organizational networks that have the capacity to create long-term value for the businesses in the facility. This article analyzes the lifecycle of a facility, which involves two major phases: the project phase and the operations phase. In regard to the content of these phases, the facility and the inter-organizational network is established in the project phase, and the facility and the network organizations co-create jointly the use value in the long-term. The purpose of this paper is to look at different types of logic on how value co-creation among multiple organizations can take place in the operations phase of the facility. Furthermore, the purpose is to identify activities in the project phase, which facilitate the development of such network that contributes to value co-creation in the operations phase. The empirical study is a qualitative single case study of a lifecycle of Rehapolis health and wellbeing campus facility in Finland. We identified five types of value co-creation logic in the operations: 1) integrated business operations, 2) shared use of premises and facility services, 3) organizational integration, 4) shared brand and marketing efforts, and 5) shared knowledge. We then identified five activities in the project phase that facilitated the creation of the network: I) creating a shared vision among stakeholders, II) building a focused campus concept, III) engaging external third party and public stakeholders, IV) creating distinctive brand and name, and V) designing and adjusting of spaces jointly. This research highlights that activities during the construction project could also include the development of an inter-organizational network which involves co-creation of value among multiple organizations using the facility in the operations after the completion of the project. By understanding the different types of logic of value creation among different operators and users, developers and investors can focus their activities already during the project on enhancing the value creation in the long term, over the whole lifecycle of the facility.

**Keywords:** Facility, Project Lifecycle, Inter-Organizational Network, Value Co-Creation, Activity

## 1. Introduction

Property developers and construction companies have continuous need to develop their businesses by providing users and tenants additional value that goes beyond the traditional value of physical premises. One trend is to create business premises for selected actors that benefit from close proximity between each other and therefore see the specific premises as strategic locations for their businesses and operations (Borgh et al., 2012; Cheng et al., 2014). According to the existing research, co-location of actors allows building trust, which in turn is a prerequisite for collaboration (Becker et al., 2003). Again, co-located facilities that enable collaboration between occupants promote knowledge sharing (Haynes and Sailer, 2011; Inalhan and Appel-Meulenbroek, 2010). Localized networks are valuable as they in addition to enabling value creation between organizations, also offer additional value for customers, especially in consumer service and retail businesses in which co-location makes possible for organizations to integrate their products and services for potential customers.

Despite of the highlighted role of built environment to provide value for inter-organizational networks, little is still known about exact co-creation logics in those networks. It could be hypothesized that additional value of premises to networks is somehow connected to the interplay between tangible aspects of the shared premises and intangible aspects of the operating organizations and their relationships. If that is true, crucial question is also how the formation of the unique network and value co-creation among multiple organizations in the operations phase could be considered already in the project investment phase? Previous research about construction projects highlight the activities to materialize physical construct for planned purposes. However, previous research says little about what are the activities during a construction project that can contribute to later inter-organizational value co-creation in the operations phase.

This article investigates a facility lifecycle from the perspective how value co-creation among actors in the operations phase is established through activities during the construction phase. The paper aims at linking the construction project to the operations phase by identifying different types of logic in value creation in the inter-organizational network identified in operations phase of a healthcare campus and further investigating how activities in the construction phase enabled realization of value co-creation. The research questions are: RQ1 – How value co-creation among multiple organizations can take place in the operations phase of the facility? We address RQ1 by analysing the lifecycle of the case facility and identifying five different types of logic for the co-creation of value among multiple organizations in the operations phase. RQ2 – How the development of such inter-organizational network can be managed during the construction project, which contributes to the value co-creation logics in the operations phase of the lifecycle? We address RQ2 by identifying activities in the management of the project that facilitate the development of such network that contributes to value co-creation in the operations.

## 2. Theoretical background: value of construction projects

Value is the fundamental purpose of exchange. In classic economic theories value refers to utility theory which states that consumers spend their money so as to maximize the satisfaction they get from products and services (Bowman and Ambrosini, 2000). In construction projects this means that clients or owners consider the balance between investment costs and estimated profits of the buildings through e.g. rents or resale value as a starting point for the investment.

In existing research about value of construction projects, additional value is typically approached from the cost minimization perspectives. Research about lean construction and target value design mostly concentrates on developing methods and practices to reduce construction costs (e.g. Zimina et al., 2012), and potential to improve benefits or profits of investments are typically less considered. However, in the book of “How Buildings Add Value for Clients” (Spencer and Winch, 2002) the authors argue that well-designed and constructed buildings have several value adding components for clients, including financial value, building’s contribution on productivity, indoor environment quality and spatial quality as well as even symbolic value of buildings in its relationship with the external environment. The value of construction has at least three dimensions: the contribution to client’s business processes (McGregor and Then, 1999), the contribution to supplier’s business processes, and the contribution that the asset makes to society as a whole (Winch, 2006).

A construction company can adopt different value creation logics in its operations. Bygballe and Jahre rest on the three dimensions of value logics - value chain, value shop and value network logic (Stabell and Fjeldstad, 1998) - as they argue that in construction the value chain and the value shop logics seem particularly relevant (Bygballe and Jahre, 2009). The value network logic describes companies that facilitate exchange between different clients and customers, for example retail banks, insurance companies and transporters. The authors suggest that “even if these services are important for the functioning of the construction industry, they do not represent what are usually considered construction activities”.

As research about construction has not highlighted the value network logic, the research on campuses and business parks, instead, sees high value in business premises that are shared among networked organizations. Science parks can support creation of formal and informal networks, which are valuable for growth of new technology based firms (Cheng et al., 2014; Dettwiler et al., 2006). Co-location with similar companies facilitates innovation processes and creation of innovation community (Borgh et al., 2012). The studies suggest, that especially for high tech companies and SMEs, the construction of shared business premises has value that goes beyond boundaries of single firms.

If we accept the notion that value created during operations in facilities has also intangible and inter-organizational nature, the crucial question is how this value creation is facilitated earlier in the project phase. Project lifecycle consists of distinctive phases, such as front-end, conceptualization, execution, and start-up of operations (Morris, 2013) which in a post-project stage provides value for several stakeholders (Turner, 2014). Parallel creation of inter-

organizational networks has been seen as a source for long-term value (Artto et al. 2016). Inter-organizational campuses are examples of low hierarchy networks in which proximity can lead to value co-creation among actors through many mechanisms, such as knowledge sharing (Inalhan and Appel-Meulenbroek, 2010), integrated supply-chains or shared resources.

Based on the research about value of construction, value of local networks, and project phases, we illustrate the development of the multi-organizational business premises through an analytical framework (Figure 1). The framework highlights the parallel creation of an inter-organizational network during the construction project. This research aim to identify the value co-creation logics of business premises in the operations phase and activities establishing them during the investment project phase.

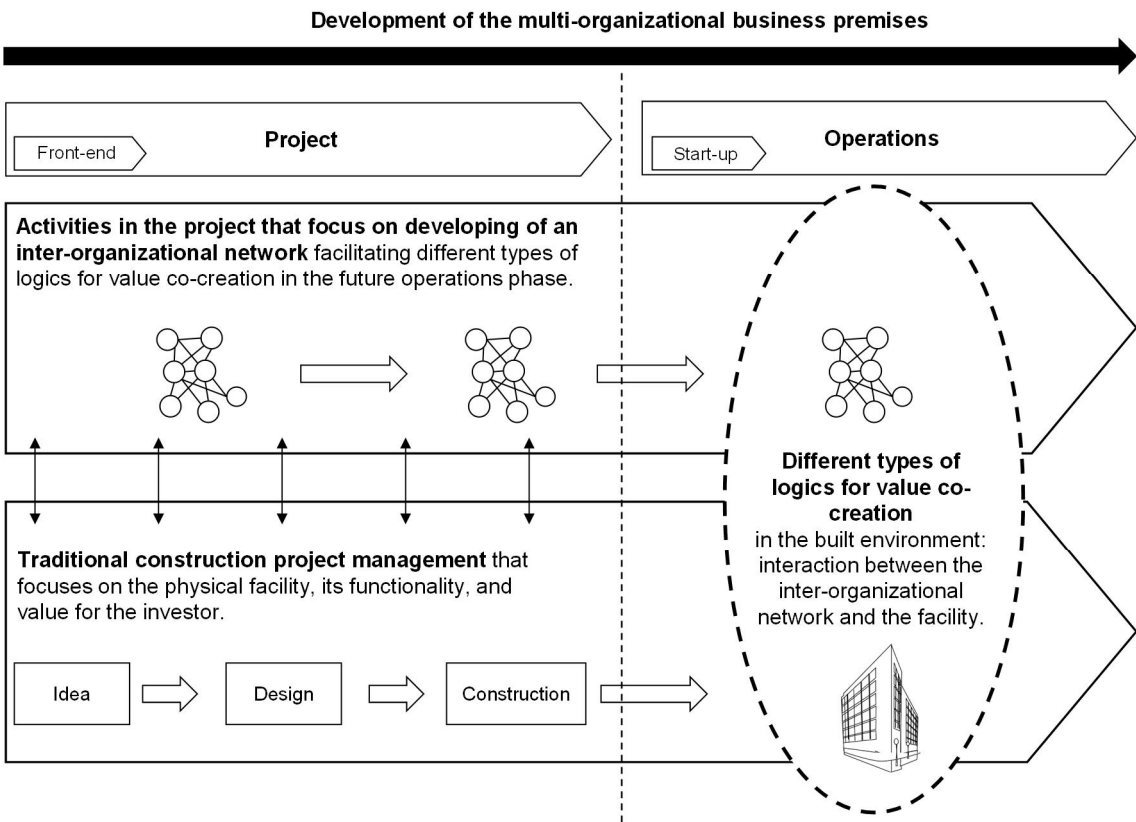


Figure 1: The research framework

### 3. Method

Due to an explanatory nature of the research question ('how'), and purpose to investigate contemporary value co-creation during operations and its connection to the past project phase, a case study method was selected to gather a full variety of evidence within a real-life context (Yin, 2003). We conducted a qualitative in-depth single case study, which analyses the lifecycle of Rehapolis health and wellbeing campus facility in Finland. The lifecycle of Rehapolis campus forms suitable unit of analysis because it included various public and private organizations which participated during the campus development project and which co-created value also during the operations phase.

### 3.1 Case description

The Rehapolis campus lies in the district of Kontinkangas next to the Oulu University Hospital and Oulu University of Applied Sciences' School of Health and Social Care, creating a close proximity of health care operators inside the district. Rehapolis consists of two buildings comprising 8500 m<sup>2</sup> of rented space and currently hosts 19 different actors ranging from private companies to public health care operators and third party associations. The main actors are operating in the field of disability health care providing all the public and private services required for acquiring assistive devices and rehabilitation services for persons with physical disabilities.

### 3.2 Data collection

The investigated construction phase including also a front-end phase spanned six years between 1998 and 2004, and an operation phase up until 2015. We collected empirical data through history documents, meeting memos, marketing materials and semi-structured interviews of representatives from 15 organizations, which had participated in the development of the facility and/or had operated on the campus. In total we conducted 24 interviews (Table 1) that ranged between 51-110 minutes. In the interviews, informants were asked to freely tell their story about the campus project, crucial events, activities and people during the project lifecycle and collaboration and activities in the operation phase.

### 3.3 Data analysis

In the analysis, we first inductively identified value co-creation logics among participating organizations in the operation phase. We identified all the features of the network or the buildings which informants mentioned valuable for them (1<sup>st</sup> level coding). After that we combined those features to the five groups which reflected different value creation logics (2<sup>nd</sup> level coding). In the second phase, we inductively mapped the crucial events and activities during the lifecycle of the Rehapolis from the front-end to the current operations phase. The importance of the event or activity was evaluated based on how often it was mentioned among informants, and how they connected the event or activity to the network formation or the establishment of value co-creation during operations. We also used deductive reasoning to identify mechanisms between activities and value co-creation if an activity had a clear outcome and if that same outcome was evidently crucial to establish a mentioned value co-creation logic.

*Table 1: Interviewed organizations and individuals.*

<i>Organization</i>	<i>Description</i>	<i>Interviewee role</i>
Public operators  3rd party	Assistive Device Unit	Unit manager
	University Hospital Prop. Management	CEO
	ORTON Foundation	CEO, Former CEO

Private companies	<i>Oulu's Disabled Association</i>	<i>An association representing the rights of people with physical disabilities. Among the first actors participating to the development of Rehapolis and bringing customer's perspective to the project. COO was the member of advisory board.</i>	<i>COO Former COO</i>
	<i>The Finnish Rheumatism Association</i>	<i>An association supporting rheumatic patients by offering guidance, help and education. Among the first users in the Rehapolis.</i>	<i>COO</i>
	<i>Respecta Inc.</i>	<i>Private actor providing all the services for assistive devices. Focal company in the creation of Rehapolis and the developer during the construction of both campus buildings.</i>	<i>General manager, Ex-CEO (2 interviews), Regional Manager, Former admin.</i>
	<i>Provider I</i>	<i>A company owned by the student union of University of Oulu, provides restaurant and catering services in Rehapolis campus.</i>	<i>Service Manager</i>
	<i>Provider II</i>	<i>A private company providing various physiotherapist services.</i>	<i>CEO</i>
	<i>Provider III</i>	<i>A private company providing solutions for hearing-impaired (hearing aids and other products &amp; services).</i>	<i>CEO</i>
	<i>Provider IV</i>	<i>A private company focusing on wellness tourisms and operating a rehabilitation and wellness centre.</i>	<i>COO</i>
	<i>Provider V</i>	<i>Private company providing medical, social and professional rehabilitation services (e.g. occupational and speech therapy).</i>	<i>CEO</i>
	<i>Provider VI</i>	<i>Private company providing assistive devices. Main focus in movement aids such as wheel chairs and walkers.</i>	<i>Regional manager</i>
	<i>Provider VII</i>	<i>Facility management company, which took over the facility management of Rehapolis 1 premises during the year 2014</i>	<i>Regional manager</i>
	<i>Provider VIII</i>	<i>Private start-up developing innovative bone implants through in-house R&amp;D project.</i>	<i>CEO</i>

Note: Private companies are anonymized due to request of the informants.

## 4. Findings

### 4.1 Lifecycle of the Rehapolis

The origin of the campus idea dates back to the late 1990s (Table 2). The advisory board of Respecta consisted several experts from the field of physical disabilities from public, private and third sector organizations. The experts met a few times a year and discussed about the needs and development trends in the field. Major concerns related to the fragmented service chain from customer point of view (e.g. in cases in which amputated patient needed assistive devices), unsound premises of several organizations.

Table 2: Key events in the lifecycle of the Rehapolis

<i>Year</i>	<i>Key events</i>
<i>1997</i>	<i>First discussions about the campus concept among Respecta advisory board members during the shared trip to the fair.</i>
<i>1998</i>	<i>First concept plan and organizing document signed by crucial public, third party and private stakeholders.</i>
<i>1998-2002</i>	<i>CEO of Respecta coordinated fund-raising, and design of concept and premises with support of other parties.</i>

2002	<i>Final decision to build Rehapolis 1. Funded by Orton Foundation and City of Oulu.</i>
2004	<i>Rehapolis 1 was opened. Respecta and City of Oulu as major operators.</i>
2004	<i>Former CEO of Oulu's Disabled Association was nominated as a Director of Rehapolis (salaried by Respecta). He launched an internal coordination body and joint marketing activities.</i>
2008	<i>Rehapolis 2 was opened. Hospital District moved in with Assistive Device Unit and occupational health centre.</i>
2011	<i>Hospital District and City of Oulu merged their Assistive Device Units.</i>
2012	<i>Director of Rehapolis retired. After short period with new Director, the CEO of Respecta took responsibility of Rehapolis.</i>
2013	<i>Orton Foundation sold Respecta to an international company. CEO of Respecta retired.</i>
2013-	<i>Occasional campus events organized. No systematic management. Actors launched new joint services.</i>

During one shared conference visit in 1997, the board members came up with the idea of a new campus dedicated for rehabilitation aid and service providers. The CEO of Respecta and COO of the Association for the Physically Disabled took leading roles in developing the campus concept and marketing it to regional public players and other potential operators. Convincing the public actors about the idea was necessary for gathering financial resources for construction. The idea took five years to mature, and the first building was erected in 2004. An innovative contracting method in which Orton Foundation financed construction phase and after that sold 20% of the premises to the City of Oulu based on the reported costs was used to speed up the project. The organizations moving on the campus had possibility to affect the design phase and customize their own offices based on the needs of their customers and operations.

The actors that moved on the campus highlighted how they felt like they belong to a same organization. That feeling was connected to the shared experience about the new premises but also to new activities mentioned by several informants: Shortly after the start of operations, Respecta recruited the COO of Disabled Association as a Director of Rehapolis. He started to organize internal marketing board meetings that focused on shared marketing efforts as well as more recreational activities among the actors. The Director was seen as a father of the whole campus and he emphasized that he was working for Rehapolis and not for Respecta.

The hospital district was not pleased with private companies leading role in the development work. However, after good experiences with the first premises, the hospital district participated in the construction of the Rehapolis 2. The hospital district moved its assistive device unit to the new premises as well as its occupational health provider. The directors of Rehapolis recruited other organizations to the building and allowed also Respecta's competitors to participate in the campus network. Several examples revealed that the network was creating value to the members as planned: The City of Oulu and hospital district merged their assistive device units which led to better management of devices and easier business environment for private providers. Respecta and Assistive Device Unit developed integrated service-chains for patients, and providers II and V launched new therapy service. The Director of Rehapolis continued to organize stakeholder events for disabled patients, potential new customers and health care professions. In summary,



the Rehapolis campus may be considered a success. Nowadays, altogether 19 organizations from the health and wellbeing sector operate on the campus.

## 4.2 Five types of logics for value creation in the operations phase of Rehapolis

We identified five value co-creation logics in the operation phase (Table 3): 1) integrated business operations, 2) shared use of premises and facility services, 3) organizational integration, 4) shared brand and marketing efforts, and 5) shared knowledge.

*Table 3: Identified inter-organizational value co-creation logics*

<i>Value creation logic</i>	<i>Description</i>	<i>Conclusion of evidence from empirical analysis</i>
1. <i>Integrated business operations</i>	<i>Organizations innovated new value adding offerings to shared customers by joining their core capabilities.</i>	<i>A joint development project of service providers (SPs) 1 and 6. The Assistive Device Unit and SP1 had common days for disabled customers to fit devices. SP 5 occupies a shop-in-shop office within SP 1 facilities. SPs 3 and 4 launched a new collaborative therapy service.</i>
2. <i>Shared use of premises and facility services</i>	<i>Improved cost efficiency through shared premises.</i>	<i>Common coffee rooms, meeting rooms and parking lots. Orton provided free office spaces for Disabled Associations. Open doors and corridors to improve space efficiency. Restaurant working as a reception desk.</i>
3. <i>Organizational integration</i>	<i>Proximity wot overlapping offerings facilitated mergers.</i>	<i>Assistive Device Units of the City and the Hospital District merged soon after re-locating on campus. SP 1 bought part of the operations from SP 3.</i>
4. <i>Use of shared brand and marketing efforts</i>	<i>Brand helped actors to market cost-efficiently, attract new customers and increase reliability of their services.</i>	<i>The name Rehapolis was launched. Brand was used to market network to new actors. Monthly money was gathered from actors for joint market campaigns and websites. Organizations highlighted Rehapolis brand in their marketing due to its identification with high-quality and familiar location.</i>
5. <i>Shared knowledge</i>	<i>Organizations increased their knowledge about shared customers and their needs through formal and informal collaboration.</i>	<i>Educational events were organized to customers and professions. Director organized internal coordination bodies and collaborative activities (e.g. evening events, joint visits, parties, guest introductions) among campus participants.</i>

*Integrated business operations* were seen especially important as shared campus location enabled providing customers more comprehensive service packages than what would be possible in scattered premises. Organizations were even able to joint their resources so that customers could not recognize any interface between the providers. *Shared use of premises* represented more

traditional value co-creation logic. However, informants highlighted that joint use of corridors, coffee rooms and meeting rooms was motivated due to the fact that most of them were operating in the same field, disabled patients. *Organizational integration* created value to actors that during the operation phase perceived that they could be stronger and more efficient if they joint their organizations. This role of shared location as a facilitator was extremely evident in the merger of the City's and Hospital District's Assistive Device Units as before the co-location the organizations had deep mistrust to each other. Shared location and shared field of services enabled also creating Rehapolis *brand* and using it in *joint marketing efforts*. Brand was especially useful for small private companies which could scale their marketing efforts and increase the reputation and quality image of their services. Finally, informants saw all informal and formal collaboration among actors valuable as it enables *sharing knowledge* across organizations and individuals. Professional knowledge about needs and services of shared disabled patients helped the actors to develop their own capabilities and offerings.

### 4.3 Activities in the construction phase for developing the network with inherent co-creation of value in the long term

The five activities were identified in the construction project phase that established value co-creation in the operating phase: I) creating a shared vision among stakeholders, II) building a focused campus concept for a shared customer segment, III) engaging external third party and public stakeholders to the concept, IV) creating distinctive brand and name, and V) designing and adjusting of spaces jointly already in the project phase. The analysis identified several mechanisms that connected the identified activities to the value co-creation logics (Table 4).

Table 4: Activities in the construction phase for developing the network.

Activity	Description and evidence from empirical analysis	Connection to the value co-creation during operations
I. Creating of a shared vision among multiple organizations in the future 'operations ecosystem'	Organizations belonging to the Respecta advisory body discussed regularly about the crucial issues of the disabled field and came up to the need to improve customer-centeredness of the services and efficient use of devices, such as wheelchairs.	Creation of shared vision about the field built ground for organizations to start discussions about joint operations. à 1. Integrated business operations à 3. Organizational integration
II. Building of a focused concept for a shared customer segment among the involved organizations	The CEO of Respecta took the leading role of building a concept about the physical campus in which all the crucial organizations providing services to disabled people have premises.	Sharing the same customer segment helped organizations to design common spaces and decide how to use them à 2. Shared use of premises and facility services
III. Engaging of external third party and public stakeholders to the concept jointly already in the project	Assistive Devices Units of the City and Hospital District, Disabled Association and Rheumatism association were committed to the construction project and to relocate offices to the new campus. The	Participation of the organizations already in the construction phase to develop the concept and finance the investment increased and tested trust between organizations and individuals. à 1. Integrated business operations

	<i>city of Oulu accepted open book policy to pay part of the realized investment costs.</i>	<b>à 5. Shared knowledge</b>
<i>IV. Creating of distinctive brand and name</i>	<i>The name Rehapolis was created in a very early phase when the building was designed in order to market the campus as a highly focused network to carefully preselected potential tenants.</i>	<i>Early creation of the campus brand facilitated selecting appropriate organisations to the campus in order find areas for collaborative marketing.</i> <b>à 4. Use of shared brand and marketing efforts</b>
<i>V. Designing and adjusting of spaces jointly already in the project phase.</i>	<i>Open door layouts, and shared meeting and coffee rooms were designed in order to enhance chance encounters between individuals and to increase the feeling of unity among organizations.</i>	<i>Design solutions supported informal and formal collaboration among actors.</i> <b>à 2. Shared use of premises and facility services</b> <b>à 5. Shared knowledge</b>

The shared vision in the field of disabled services was already created in the project front-end phase. Different private and public actors met occasionally and discussed about needs to improve service chains. They also finally came up to the idea about the shared premises under which customer could get all crucial services and devices. Early discussion about the shared vision among organizations in the project phase created fertile ground for later discussions about detailed joint operations and organizational integrations. Building of a focused campus concept in the early phases of the project enabled to design premises that were tailored to specific needs of disabled patients and service providers. One of the service providers took leading role in developing the campus concept and also to involve other organizations in the space design. That enabled design of tailored spaces and shared rooms which were considered valuable and unique in the operating phase. The target customer group was also focused enough in order to design specific accessibility solutions.

Engaging external third parties and public stakeholders to the concept design and campus construction were crucial activities that built legitimacy for the project among society in the Oulu region. Public-private partnership was also used to speed up the project development phase and finance the delivery innovatively based on the open book practice. The collaboration already in the project phase created trust between the organizations and helped them to create joint services in the operation phase. Different stakeholders also brought their own expertise to the project and the network creating basis for the knowledge sharing in the operation phase.

The campus brand was created in the project phase and used to recruit appropriate organizations to move to new premises. That made possible to ensure that actor mix of the campus had enough coherence which was seen crucial in joint marketing efforts. The development of the brand early enough improved also the image of the new premises enabling campus developers to select carefully most suitable actors to the localized network. The role of campus premises as a platform for collaborative value creation was taken into account in space design phase. Open corridors and shared meeting rooms were designed to enhance chance encounters between individuals and

organizations. This activity also established value co-creation through shared knowledge. The layout supported informal encounters and sharing of crucial information among actors.

## **5. Discussion**

The investigated case study represented the development of the business premises in which the end result was a unique network of actors which operated in the unique premises designed and constructed for their specific purposes. The campus was success both for its owners and tenants as actors in the campus were willing to pay extra rent on the additional value they got from the network and surrounding premises. Through an in-depth analysis of the campus lifecycle we could identify five value co-creation logics and five activities to establish them in the project phase. The analysis was conducted in single case settings and exhibits “the force of example” (Flyvbjerg, 2006) about the links between project phase activities and value co-creation during operations. We argue that the findings have at least two contributions to the existing research.

First, the study shows how value of construction and buildings could be materialized through a development of unique network of organizations operating in shared location, and through a support of project outcome to the value creation in the operating phase. A building or shared location can catalyse several logics contributing to value co-creation. Some of those logics have tangible dimensions, such as shared premises, whereas others are more intangible or even strategic, such as organizational integration. Compared to previous research that has separated value logics mostly from a single organization perspectives (Spencer and Winch, 2002), this research broadens understanding about inter-organizational value creation in built environment.

Second, the study identifies five distinct activities in the investment project phase that were connected to the value co-creation in the operating phase. As the design of campuses and science parks with inter-organisational networks has been on the agenda for decades (McAdam and McAdam, 2008; Quintas et al., 1992; Kyrö et al., 2016), the study increases understanding about details how that value co-creation can be already affected through design solutions and collaboration in the project phase having direct implications on the success of the local network. We argue that in successful investment projects and in successful network development, the tangible development of the premises is tightly connected to the network formation through collaborative activities that both make premises more suitable for the network and also formulate network and relationships between its organizations early enough to maximize value creation in operation phase. The commitment of the network organizations to achieve the physical outcome of the project commit them simultaneously together for the purpose of value co-creation.

## **6. Conclusions**

The aim of this paper was to identify what are the value co-creation logics among organizations in localized inter-organizational networks and what are the activities during the investment project that establish such value co-creation. The research provides new knowledge about value of buildings which is related to collaboration among actors in shared premises. This knowledge is especially important for facility managers that develop new value-adding services in existing

facilities and for developers and construction companies that in the early phases of the project want to establish high value of the premises during operation phases. For those organizations the study provides detailed knowledge about activities that contribute to lifecycle value of buildings. By understanding the different operators' and users' value creation logics, developers and investors can orchestrate activities during the whole project lifecycle in order to maximize value in the inter-organizational network.

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# An exploratory study of the practice of stakeholder participation in densification projects

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## Abstract

**Background:** For decades, densification has been adopted and enforced by policy makers and other stakeholders to achieve a more sustainable built environment. However, scholars argue that densification is merely a tool and alone is not sufficient to achieve sustainable development. Furthermore, densification projects can bring negative as well as positive impacts for stakeholders. Negative impacts include increased housing prices and construction cost, pollution concentration in urban areas, reduction of public and green space, and unhealthy living environments. On the other hand, urban densification can contribute to a more attractive environment by increasing the efficiency of transportation, concentration of services, social integration and reduction of buildings footprint. A holistic approach to densification is needed which takes into account social, economic and environmental sustainability aspects.

**Objectives:** Stakeholder participation contributes to sustainable densification by taking into account the needs and concerns of a wide range of stakeholders throughout the different stages in the development projects. The aim of this study is to explore the current practice of stakeholder participation in order to identify the challenges, opportunities and best practice of stakeholder participation in urban densification projects.

**Methodology:** This paper explores the current practice of stakeholder participation in densification projects and its potential benefits and hindrances, through a literature review and interviews with stakeholders in the public and the private sector as well as the affected community.

**Results:** The results of this study show that best practice of stakeholder participation in densification projects is characterized as proactive actions taken by individuals and groups rather than at an institutional level. Moreover, the impact that these proactive actions have on project success can contribute to the promotion of stakeholder participation at an organizational and institutional level.

**Keywords:** Built environment, densification, participation, stakeholders, sustainability

# **1. Introduction**

The concept of sustainable urban development refers to the process in which social, economic and environmental issues are actively considered throughout the stages of the development project, i.e. planning, design, construction, and operation. Sustainable urban development is characterized as a means to achieve more than just built environments that reflect the needs and interest of a wider society. The lack of collective understanding of sustainability among the wide range of stakeholders in the planning, design, implementation, operation and maintenance of property development projects has been identified as a hindrance to achieving sustainable urban development (Curwell et al., 1998). Recent studies on sustainable urban transformation show that only a few powerful initiatives are driving urban development in a sustainable direction and conclude that key aspects for achieving sustainable transformative change are planning and governance (McCormick et al., 2013). Furthermore, evidence shows that collaboration between local government and cultural institutions increases local government capacity by strengthening resources and improving political efficacy and governance, thus leading to better credibility with the citizens and increasing networking and political capacity (Gough & Accordino, 2013).

Densification is proposed as one of the essential strategies to achieve a more sustainable living environment in cities. Although there are benefits to a more compact urban form, there is evidence that densification might lead to gentrification of existing urban areas, thus contributing to inequality and social problems (Quastel et al., 2012). Therefore, methods are needed to balance the social, environmental and economic sustainability aspects in urban densification projects.

The purpose of this study is to obtain explanations of how stakeholder participation potentially could solve the social sustainability problems that densification projects may infer. By performing an inductive literature review and a qualitative interview study we study the current state of the art and the current practice of stakeholder participation in densification projects in Sweden. The results shows that many practitioners are working in some level with participatory processes, however, only a few have institutional and organisational support for these processes. Furthermore, there are a lot of benefits to involve stakeholders; however practitioners are finding stakeholder participation complex and challenging. In spite of the complex nature of stakeholder participation, however, it was noted that taking the risk to implement a stakeholder participation process can contribute to project success. Moreover, the impact that these proactive actions have on project success can further promote stakeholder participation at an organizational and institutional levels in organizations.

## **2. Stakeholder participation**

Inadequate management of the concerns of stakeholders can lead to controversy and conflict about the implementation of the project (Olander and Landin 2008). Community attitudes are one example that has been shown to be an important factor when planning for, and locating, a development project (Rogers 1998). The demands of different stakeholder groups vary and a project can benefit one stakeholder group whilst simultaneously having a negative impact on others. Understanding the viewpoints of different stakeholders helps the project manager build



relationships and thus avoid preconceived ideas and assumptions (Watson et al. 2002). To ensure stakeholder participation, especially by stakeholders in the external environment, various analyses and mapping techniques are available (e.g. Olander and Landin, 2005, Bourne and Walker, 2005, Olander, 2007). Different stakeholder groups have been analysed depending on their possibility to influence project decisions, and the potential consequence, for the project, if they choose to do so. An understanding of stakeholder theory is relevant in order to fully understand the numerous trade-offs that exists in sustainability-related problems (Hörisch et al. 2014). Stakeholder theory implies that successful organizations recognize stakeholder interests in a continuous process with the aim of creating value for a broader perspective of stakeholders (Strand and Freeman 2015) through, for example, a participatory process.

Arnstein (1969), argued that participation is the redistribution of power to those excluded from the political and economic arena to take part in the decision-making process. It is often argued in the participation literature how participatory practices are often proven inefficient. An inefficient participatory practice leads to failure in meeting the needs and concerns of the public and hence failure in improving the quality of the decisions and incorporating a wide range of stakeholders (Innes and Booher, 2004). With her work from 1969, Arnstein argued that approaches to genuine participation must safeguard stakeholders' needs and concerns in the decision-making process. Yet, even best-intentioned experts are prone to be unfamiliar with the problems and aspirations of stakeholders (Arnstein, 1969). Furthermore, scholars argue that there is not one universally effective method to participation as different methods are highly dependent on the contextual and environmental factors embedded in the project (Smith et al., 1997).

Three approaches to justify public participation have been identified in the participation literature (Stirling 2006; Fiorno, 1990) these are categorized as normative, substantive and instrumental. As opposed to the substantive arguments, normative reasoning focuses on the democratic rationale and is considered an end in itself. The focus is on equality rather than on the quality that comes out of the process. The substantive arguments look at participation instead as a means to an end, with an emphasis on improving the quality of the decisions made i.e. by incorporating local knowledge into the decision-making process. The third ground for public participation, the instrumental reasoning, considers public participation as a means to re-establish credibility and trust, and how to make decision more legitimate through public participation.

Innes and Booher (2004) mention how participation models exclude the participation of a broader range of stakeholders. Participation is often perceived as a dual system that involves citizens and the government but fails to integrate other stakeholders in the model. Innes and Booher (2004) argued that participation must be perceived as a collaborative process that engages a wide range of stakeholder's citizens, special interests groups, non-profit organizations, private and public sectors where communication, learning and action are essential for meaningful participation. However, as argued by Brody (2003), broad participation in the planning process does not necessarily lead to better plans; it is instead the involvement of specific stakeholders that significantly increases the quality of plans. Instead of engaging as many stakeholders as possible, Brody (2003) suggests that focus should be placed on identifying and involving specific stakeholder groups that are likely to enhance the quality of decisions. For example, a study in

participatory urban planning in Helsinki by Kyttä et al. (2013) presented a SoftGIS methodology for the production of location-based, experiential knowledge from residents and found that contextual and experiential information from residents can be valuable for planners and further serve as a new layer of 'soft' knowledge in the planning of urban densification projects.

### **3. Urban densification**

During the last 50 years, the suburban footprint has been expanding much faster than the core city (EEA 2006). This suburban expansion has been called urban sprawl, because the urban footprint is big but scattered. Frumkin (2002) and Ewing et al. (2013) have shown that there are many negative aspects to an urban sprawl development, both on its inhabitants and the environment. Urban sprawl removes the previous functions of the land, be it agriculture, industry or nature, and replaces it with single-family houses with garden plots. Because this sprawl is so widespread, inhabitants are more prone to use cars as a primary means of transportation, which in turn causes CO<sub>2</sub> emissions, pollution and obesity. The solution to the problems caused by urban sprawl is a densification of the built environment. Studies reveal that compact, mixed-use, and high-density development served by public transit produces lower carbon emissions than conventional low-density suburban development (e.g. Senbel and Church, 2011).

Densification remains a heavily contested concept (Quastel et al., 2012) and its complexity and multidimensional view causes misinterpretation among practitioners and proponents of densification. Due to the many interpretations, densification often leads to conflicting requirements and different results. Despite the benefits that urban densification projects bring, these kind of projects are often socially conflicting and require planning strategies and solutions that are tailored to the local context and respects the residents' local experiences (Kyttä et al., 2013). Furthermore in order for cities to accommodate an increasing population, socio-economic changes need to be taken into account than simply providing housing and promoting densification (Turok, 2011). Density is one of several components to achieve a more sustainable urban environment. Overlooking other important factors such as distribution of employment opportunities and planning of transportation systems reduces the potential for lasting sustainable solutions (Dodman, 2009). Urban development projects have negative effects and the likelihood increases when sociocultural dimensions of the urban environment are not taken into account. Thus, if the compact city is to be adopted, urban infill such as housing must be tailored and comply with the people's perceptions about the developed area (Vallance et al., 2005). Densification as the means to achieve sustainable development has faced increased opposition from residents, community groups and social activists concerned with gentrification and housing affordability (Quastel et al., 2012). Moreover, the goal to achieve compact transit-oriented urban environments is seen by residents and other stakeholders as a vision that is imposed against their wishes and without their consultation (Senbel and Church, 2011). To create attractive cities where people from different socio-economic backgrounds can cohabit requires new and improved services, amenities and public spaces that are tailored to the needs and desires of a wide range of stakeholders. Furthermore, it is proposed that a participatory planning approach can contribute to enhanced cooperative relationships and help create more stable and cohesive sustainable communities (Turok 2010).

### **3.1 Densification process in Sweden**

The population continues to increase in urban areas and there is a clear trend towards densification of cities. Moreover there is a trend towards mixing different functions: living, commercial, work and leisure activities. Parts of most of our cities undergo transformations related to commercialization, land use and increased density of buildings. The fact that an increasing proportion of the Swedish population lives in urban areas has resulted in the development of cities to achieve the national goal of sustainable development. A recent parliamentary report notes that densification and increased mixing of the city's various functions is a current trend in today's urban development (Swedish Parliament, 2011). Concentrating cities increases the resource efficiency in several ways (Hansson 2011, Swedish parliamentary investigations, 2012).

The Swedish National Board of Housing, Building and Planning monitor the function of the legislative system and proposes regulatory changes: they also represent Sweden in the European Commission. In 2012 they published their vision of Sweden in 2025 (Swedish National Board of Housing and Planning, 2012). In this vision, one of the ways to achieve a more sustainable living environment in and surrounding cities is through densification. There are also plans for densification in local regions (WSP, 2013). Each of the three largest cities in Sweden - Stockholm, Gothenburg and Malmö - have developed individual plans for densifying their built environment (Ståhle et al., 2009, Brunnkvist et al., 2014 and Jönsson et al., 2010). From these documents, it is clear that there is a governmental, regional and municipal willingness in Sweden to densify. Several of the key factors in the concept of densification are mentioned in the documents such as: local business, improved infrastructure, more efficient recreational space, reduction of car traffic and increased pedestrian and bicycle traffic. Nonetheless, these documents do not fully explain how and why these measures are necessary to achieve a more sustainable development, neither do they explain the positive and negative aspects of densification in cities.

## **4. Methodology**

The research reported in this paper used interviews as the main mean of gathering data. A total of ten interviews were conducted with people who are actively working with densification projects and stakeholder participation. Ten interviews were conducted with city planners, civil servants, municipal developers, facility managers, private developers and housing cooperative members. In order to obtain realistic knowledge of the current practice of stakeholder participation in densification projects we needed a method of data gathering which allowed a more flexible approach than most methods offer; therefore we chose interviews as the means of data gathering (Alvesson, 2011). Semi-structured interviews allowed us to gather their experience and observations through a partially open discussion about the subject, thus providing richer descriptions than if we had used another means such as questionnaires. Because the interviews are semi-structured, data are both inductive and qualitative. A data-driven coding of the interviews was chosen as suggested by Kvale and Brinkmann (2009).

The transcribed interviews were structured in a bottom-up approach in four steps: transcripts (bottom), codes (lower middle), categories (higher middle) and themes (top). The transcripts are

the written interviews. The codes are short and like keywords they summarize a sentence or a small paragraph, thus reducing each transcript from a few pages to something like 30 codes. When categorizing the codes, we searched for links between the codes, where each category consists of a few codes. Finally, we searched for overarching themes for the categories, searching for relations and synergies between our categories. Thus, we created explanations that are logically compatible with our set of data. The results and analysis of the study are structured under seven themes identified from the interviews.

## **5. Results and analysis**

### *Theme 1: Challenges and opportunities for urban densification*

The majority of the project proponents said that when densifying in existing areas, ideal land for development is usually on existing hard surfaces, parking space or demolished building sites; however densification can also occur on existing green areas. The challenge for project proponents is to strategically choose potential areas for densification by selecting areas not used efficiently and not those cherished by the residents. Densifying in green areas that have a significant value for the residents could result in a strong opposition towards the densification project. Another challenge related to densification in existing green areas is that of high-rise building to increase high-density environments. One interviewee stated that high-rise housing development requires larger areas around the buildings which can result in dysfunctional areas. Moreover, high-rise building can create wind problems and blocks access to direct sunlight, which people may find objectionable.

Many of the interviewees stated that densification does not lead to sustainable development in general and there is uncertainty about what densification will lead to. Doing densification on a sustainable basis varies and it is after several years that one can see if densification has been successful or not. Nevertheless, the project proponents have a shared view of the opportunities and advantages to a denser city; these include the reduction of car traffic, increased use of public transport and increased attractiveness of the area.

The majority of the project proponents felt that densification has the potential to convert homogeneous residential areas into more attractive areas by filling gaps and deficiencies through a mix of housing types and functions. These, in turn, can bring a better socioeconomic mix of residents and high-social diversity.

### *Theme 2: The Importance of collaboration among a wide range of stakeholders*

Another key theme that emerged from the interviews is the need for a wide range of stakeholders to collaborate in densification projects. The project proponents seemed to share the view that urban densification is complex and requires innovative solutions in the allocation of land and functions; therefore, planning for sustainable solutions should be given appropriate time and resources. According to some of the interviewees, it is uncertain if urban densification will lead to sustainable development, although it has the potential to do so. Densification strategies were

implemented in the areas affected by the “million homes program” built in 1965-1975, with the purpose of revitalizing them to make them attractive by solving the prevailing inefficiencies. At the same time, there are political goals for doubling the housing stock in these areas. The complexity of densification projects rises when these are developed in existing built-up areas. Because of the increased complexity, it is vital that a wide range of stakeholders are involved in the development of local plans. The process may require more time and resources, but the end-result will be better.

### *Theme 3: The Swedish Planning and Building Act and stakeholder participation*

The majority of the interviewees linked the stakeholder participation process to the Swedish Planning and Building Act. The Act states that when a proposal for a development plan is drafted, the municipality should consult a wide range of stakeholders who have an essential interest in the development plan. The purpose of consultation is to give stakeholders an opportunity to influence and provide insights to the decision-making process. A number of public officials in charge of procedural planning issues have made strong efforts to engage stakeholders from the different city planning administrations in the planning process. In addition, initiatives for dialogue have been employed to engage other stakeholders outside of the organization such as developers, land owners, property owners, contractors and the public. Stakeholder groups such as citizens, co-operative tenant owners, residents and community organizations are traditionally involved during the public consultation period when municipal officials present and inform them about their plan proposals.

Stakeholder participation initiatives differ among the various municipalities. While some municipalities have focused on trying higher levels of participation by means of different methods and activities of engagement, other municipalities have focused on following what is required by the legislation in the public consultation period. The period is a minimum of one month with one public meeting where public authorities present the plan proposals in front of a wider audience. Even so, public meetings are insufficient as there is a risk that conflict may arise from a discontented public which may need to employ other means of dialogue. Another challenge is that certain groups of individuals often dominate the meeting while other groups do not dare, or bother, to participate.

### *Theme 4: Stakeholders and purposes for stakeholder participation*

In general, the interviewees pointed out that it is vital to involve a wide range of stakeholders at different levels and stages of development projects. Planners have made efforts to engage with property owners, land owners, developers and different administrations in the municipality early in the planning process. In addition, efforts have been made to collect the opinions from the community within the affected areas. Housing and commercial developers, as well as facility managers, highlighted the importance of engaging with a wide range of stakeholders early in the development process.

Further, it was mentioned that opponents to the project and their concerns needed to be considered early in the development process. The developers and facility managers mentioned that they had made efforts to engage with residents, costumers and businesses. Although there is an interest in involving a wide range of stakeholders early in the development process, it can be challenging for municipal organizations and property development companies to identify and engage residents, neighbours, potential residents and community organizations.

*Theme 5: Individuals and groups experiences and abilities as driving forces for stakeholder participation*

Another key theme that emerged from the data was the individuals' and groups' abilities to leverage support in the organization to conduct stakeholder participation processes in planning and projects. From a city planner's perspective, certain project leaders and project groups in charge of planning processes were identified as strong enablers of more ambitious stakeholder participation processes that aim to engage a wide range of stakeholders. These participation processes are generally implemented in parallel with the public consultation procedure which is mandated by the Planning and Building Act. The majority of the interviewees from the municipal organizations reiterated their determination to perform such ambitious participatory processes on an individual level rather than on an organizational level. This driving force is linked to the individuals' personality, experience, interests and resources.

From a developer and facility manager perspective, individuals and groups within the organization have developed methods and strategies for participation in the development and refurbishment of facilities. These initiatives include methods for different levels of participation, customer plans and activities to get to know their customers and residents. Most of these initiatives are implemented in small scale projects or renovation and maintenance.

*Theme 6: Stakeholder participation practices, contribution, enablers and challenges to the organization*

The municipal organizations interviewed have recognized that in certain cases, traditional public consultation practices are not enough and demand new methods and practices to involve stakeholders. Civil servants within the municipalities have a shared challenge of conducting extra activities as public consultation can demand more than one public meeting. Such activities vary and can take the form of engaged focus groups, meetings and outreach in the neighbourhood to inform people about the planned proposals. Furthermore, the majority of interviewees stated that they are trying to move away from the traditional practices of one-way communication to more engaging forms of participation. Some of the interviewees explained that recently, they had started to influence the design of public consultation activities to include more engaging practices. For example, instead of holding a presentation of the project in the form of one-way communication, they hold dialogue forums, workshops and transect-walks in the affected area. These activities have proven to be highly beneficial as they facilitate better dialogue between the stakeholders and help to increase mutual understanding and knowledge about plan proposals. Moreover, there is an ambition for the municipality to inform and engage more stakeholders, especially those on the

periphery of the decision-making process. These efforts include the distribution of invitations and information through different means of communication.

Early involvement has been identified by the interviewees as an important factor to successful stakeholder participation. The involvement of stakeholders in the early stages of the development process can contribute to good dialogue and lead to positive effects such as better project outcomes and legitimacy. On the contrary, not involving stakeholders early in the process can lead to conflicts and resistance to the desired change. According to an interviewee from a property development company, actions to involve the residents and other affected stakeholders are taken during the later stages of the project with the purpose of seeking project acceptance. However, there are plans to work more proactively by involving stakeholder groups earlier in the process.

Proactive actions to stakeholder participation in new building production seems to operate at an information level where meetings are held to present plan proposals to tenants and residents as well as to listen to their opinions. Some of the reasons for the information levels of participation are the project complexity and the decision making process. It is the public consultation period in the formal planning process where the residents, neighbours and other affected stakeholders have the possibility to provide their comments on plan proposals.

According to the interviewees, some of the challenges to participation processes are associated with the lack of experience from stakeholders such as residents and neighbours to work on this set. Consequently, the lack of experience and understanding of participation processes makes it hard for these stakeholder groups to understand the motives of the process, their contribution, procedural practices and a visionary perspective. Furthermore, participation processes can be time consuming and there is a risk for participants to suffer from participation fatigue. In addition, the inability to implement the outcomes of participation processes in a short time can cause disillusion among participants for not being able to see their contribution implemented in a short period. The lack of experience in development processes and time consuming development practices can make it difficult for participants to handle participation processes.

#### *Theme 7: Institutionalizing stakeholder participation*

Another key theme that emerged from the interviews was the need for stakeholder participation to be part of the organizational culture to leverage support to the institution. It was pointed out that without the support of management; it is difficult to introduce new working practices and new ways of thinking in the organization. However, there have been cases where ideas originated from grassroots' levels in organizations have influenced managerial practices. It was pointed out that stakeholder participation initiatives and competences remains at an individual level within organizations; thus, it is vital to collect and systematize these practices in order to make them part of the organizational culture.

The interviewees seemed to share the view that stakeholder participation requires reshaping the way that institutions are organized and further identified different suggestions and capabilities to achieve this. Furthermore, it was mentioned that it is essential that project initiators feel able to

apply stakeholder participation practices and further inspire individuals in the organization to believe in it by showing the benefits achieved from conducting early stakeholder participation. Another suggestion is the need to build on existing competences in stakeholder participation practices within organizations. One way is to conduct participatory approaches in small scale projects to acquire a foundation of practical knowledge and skills that are essential when working with all types of projects. In turn, the outcome of this knowledge development can contribute to the organizational culture.

## **6. Conclusions**

Efforts have been made to implement collaboration platforms to engage various stakeholders in urban development processes. These range from external dialogue processes with private actors and community groups to internal dialogues to coordinate the interests of different administrations in municipal organizations. It is also evident that municipal organizations follow the Swedish Planning and Building Act procedural requirements to coordinate the interests of the general public in formal planning processes. Moreover, developers also depend on the legislation procedures to engage the general public in the development process. However, the lack of clear guidelines in the legislation on how to conduct a stakeholder participation process requires municipal organizations as well as developers to conduct participation processes in parallel with the procedural requirements from the legislation. These proactive measures are the result of municipal organizations' initiatives as well as joint collaborative actions where municipalities, developers and even the community sector have joined forces to conduct stakeholder participation processes.

From the developer's perspective, the project manager has the responsibility to identify and manage the various interests that will influence the project. On commercial building projects, customers are involved early in the development process as opposed to new-build housing projects. It is a challenge to involve future residents in the development of housing projects as they are often unknown. However, it is more common to involve residents in housing renovation projects as the users are known. According to developers, it is important to involve residents and the public in the making of plans and proposals. Failure to do so can create mistrust about the plans and further bring opposition to the development project. Furthermore, it was important that the formal planning process is able to balance and coordinate the interests from the developers, the wider public and other stakeholders.

Municipal officials recognized that when conducting a planning process they should consider all potential stakeholders right from the start. Today, municipal officials are discussing the involvement of a wide range of stakeholder groups, especially those that are normally underrepresented early in the planning process such as residents, local organizations and citizens. Therefore, it is vital to be open-minded when identifying and involving the stakeholders. Developers have also recognized the importance of involving known and unknown customers, residents and authorities, as well as possible project opponents to get their input early in the planning process to increase the quality of plans and projects. It is believed that the outcome will be a more efficient project process in terms of quality, time and cost.



Due to the complexity of densification projects and the requirements with respect to sustainable development and climate change, traditional public, private and community sectors roles will need to expand. Different sectors will be required to collaborate in their developmental activities in order to reach solutions that comply with the needs and concerns of various stakeholders and those responsible for the environment. A collaborative approach to stakeholder participation that combines forces between the public, private and community sectors will be necessary. The next step of the research will be to conduct a study of the practice of stakeholder participation in urban densification projects in Scandinavia and further evaluate best practice stakeholder participation processes.

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# Identifying client roles in mainstreaming innovation in Australian residential construction

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## Abstract

Adopting sustainability as an innovation in the Australian residential construction sector is constrained in an industry characterized by mass produced standardized new home production. Traditionally perceived as supply-led the residential construction procurement model inhibits the ability of consumers to demand change, or for innovation to be consumer demand-lead.

This research adopted Heywood and Kenley's consumption-based demand and supply model for corporate real estate as a framework for understanding the roles and relationships in the Australian residential construction industry, in particular the volume homebuilder as a key client for innovation from its supply chains.

The investigation provides an informed understanding of demand and supply-side structural relationships in the residential procurement process. The research identifies how innovation and change, particularly towards more sustainable homes, can be enabled through the Australian residential housing industry's current mechanisms.

**Keywords:** Australia, clients, demand-supply model, innovation, residential construction

# 1. Introduction

The Australian residential construction sector produces over 180,000 dwellings worth AU\$33 billion per annum (HIA, 2014; Australian Bureau of Statistics, 2014) and is also worth approximately 4% of Gross Domestic Product (Dowling, 2005). Currently sustainability's limited wide-spread incorporation constitutes an innovation inhibited by industry structures – a mix of relatively few large Volume Builders and relatively many small or micro businesses. Small construction business' innovation was studied by Thorne et al. (2009) and while small firms can innovate with sustainability, by market share their effect is minimal. If large-scale innovation by way of sustainability is to be achieved then engaging with mass production players and processes is necessary.

While there is debate about costs of sustainability and consumers' willingness to pay, Australian consumers have shown a propensity over many years to pay for additional 'lifestyle' features that do increase housing costs. This was seen in the 1970s' and 80s' with the inclusion of 'rumpus room' innovation offering visions of bucolic family recreation and in more recent innovations features like 'media rooms', 'alfresco' outdoor dining areas, and parents' retreats offering similar visions. Whether these are 'demanded' by customers or 'supplied' by providers as part of their competitive strategy is an open question for this paper. Nevertheless, given this consumer propensity this research proposes that sustainability innovations can become latent demand by the way they are incorporated into product offerings, particularly those from Volume Builders.

This suggests a new perspective is needed to examine the key stakeholders that can enable and drive change through the construction-property supply chain, whilst engaging the end-user, the housing consumer, in the process to create latent demand for sustainability. That perspective is provided here by applying Heywood and Kenley's (2010) consumption-based demand and supply model to the Australian residential sector to isolate opportunities for innovation and sustainability's integration into mainstream provision of housing in Australia. Three case studies demonstrate this model's effectiveness and to draw out key elements of the model's application.

## 2. Volume Builders in the Australian Market

Large Volume Builders are dominant housing suppliers across Australia, though much is made in the literature about the number of businesses in the industry – 320,000 cited by Dalton et al, (2011a) and 30,000 by Dowling (2005) – and their small size – an average of 1.4 and <2.5 employees, respectively. Volume Builders are the sector's powerhouse providers as can be seen in their market share and economic performance. Over different but overlapping ten year periods the top 100 builders accounted for between 37% and 41% of all new housing (Dalton et al, 2011a; Dowling, 2005). Within that top 100, the top 20's share was typically between 56 and 61% and the top 5's share was about 40% of the top 20's share and increasing over time (Dalton et al, 2011a). By economic performance, businesses worth more than \$10 million averaged operating income per employee of more than \$1.2 million compared with \$0.15 million for the many small businesses valued between \$100,000 and \$500,000. By economic value adding these large firms do so at 4.0 times the rate of the small firms (Dalton et al, 2011a, Figure 38). Taken together,

these characteristics point towards an oligopoly operating (Coiacetto, 2006), despite the plethora of small to micro-firms in the sector. Oligopolic behaviour is evident in the Volume Builder's ability to tell housing consumers what they want, how they want it and they do this by providing limited choices to maximise efficiencies of scale and profits (Reardon, 2013). In Australia though, this is subtly disguised as marketing a 'lifestyle', as evidenced by trends in various additional features that have been offered over time.

Typically, the process of buying from Volume Builders does two things. One, it reflects Volume Builders' dominant competitive strategy which is to create a standard set of plans, often containing attractive 'features', with some choice in materials, finishes and options enticing consumers to build with them, whilst providing what appears to a wealth of options (Barlow, 2003, p. 92; Dalton et al., 2011b). Two, is to give infrequent purchasers with limited knowledge of residential construction processes, a sense of empowerment while guiding them in their choices of dwelling, features, finishes and certainty of the price and product to be delivered (Barlow et al. 2003; Dalton et al., 2011b). These houses can be built as 'speculative' houses often as 'display homes' ahead of customer purchase or in response to customer orders (Dalton et al., 2011b).

Traditionally and theoretically (as discussed below), Volume Builders are considered as part of the supply of housing products procured by consumers. However, their relationship and interaction with other stakeholders suggests otherwise. Their size and market dominance means they can dictate to consumers and the other stakeholders in their supply chain (up to 108 trades and suppliers exist in this supply chain (Dalton, et al., 2011b, Tables 3 to 9)) their needs, requirements and to an extent price commanding cost efficiency, quality and timely delivery. The power relationship is established in the quantity and size of financial contracts with their supply chain which are not for a single house, but for 100s or 1,000s of homes. Consequently, for the trades and the suppliers (some of those 30,000 or 320,000 business noted above), this contract maybe their sole business. As a result, the requirement to perform in terms of cost, quality and time is imperative to maintaining their contracts. The Volume Builders also have a power position in choosing suppliers and trades, with a few notable exceptions where some products, like Colorbond metal roofing material, have sole or limited suppliers.

The standard residential building process in Australia comprises a variant of the *Design and Construct* procurement approach. This is utilised generally across the industry from the small contractors meeting localised demand (traditional 'Master Builders') to large state or national businesses (Volume Builders) operating across several geographic regions. Innovation in this model, theoretically, can originate from consumer demand but more realistically is dependent on the contractor, or to a lesser extent their design consultants. This is indicative of engagement in innovation within the construction sector which commonly focuses on supply-side initiatives with relatively limited evidence in the construction literature examining the consumer and client perspectives. Tombesi (2006) explores procurement, mainly in the commercial sector, and discusses stakeholders' engagement in innovation, their different roles and innovation's integration into the supply side. He also examines consumers', clients' and users' different roles in terms of their engagement in innovation. This has implications for understanding the residential

property sector and its adoption and production and integration of sustainability in new home production.

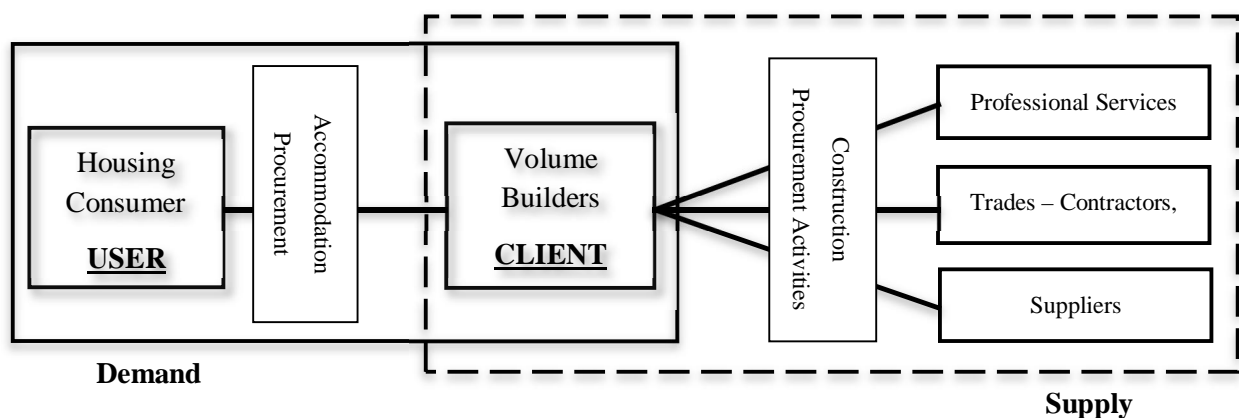
This contemporary Australian approach to new housing has proven problematic in mainstreaming sustainability in new housing (Pitt & Sherry, 2014). However, if viewed with a different lens, opportunities can be identified where sustainability and innovation can be integrated into the system that drives change in products available to end users and down the supply chain. This may then achieve long-term change within the sector. This suggests that a revised model for the relationships in new housing is required and will be useful in mainstreaming sustainability.

This research focuses on the broad scale practice in the residential property industry which is dominated by Volume Builders. Innovation in the residential property sector is either, incremental – channelled indirectly from homebuyers’ preference for products, or mainstream in response to mandatory requirements and legislation. However, to engage in sustainability’s incorporation into housing’s mass production, a new perspective is needed to examine the key stakeholders that can enable and drive change through the supply chain, whilst engaging the end-user, the housing consumer, in the process to create latent demand. This involves understanding the roles of key demand drivers in the residential property sector and how that different perspective creates levers to drive sustainability as innovation in the sector.

When viewed from a power dynamics perspective founded in the oligopolic industry structure and the Volume Builders’ substantial financial and contractual power with supply chain stakeholders, Volume Builders shift from the supply-side to a key demand-side stakeholder. Then they actually operate as a sophisticated ‘client’ in the supply chain in their procurement relationships for construction products and services. Consumer demand theory supports this approach (European Commission, 2012), where the Volume Builder as a key demand-side stakeholder will and does have the opportunity to drive change, in this case the ability to mainstream sustainability into the volume housing sector. Therefore, the research proposes that both the homebuyer and the Volume Builders are demand-side stakeholders; with the homebuyer being the ultimate housing consumer or user (Figure 1).

### 3. Method

Based on the dominant procurement model in Australian residential construction, its power relationships and consumer demand theory this research proposes that Volume Builders shift from being part of the supply side as assumed in typical *Design and Construct* models to a key demand-side stakeholder. This suggests that a revised model for the relationships in new housing is required and will be useful in mainstreaming sustainability (Figure 1). This alignment of key demand stakeholders has been adapted from Heywood and Kenley’s (2010), commercial property framework which identified an ‘*Integrated Consumption-based Demand and Supply Framework*’. It has been modified here to reflect the new residential property sector.



*Figure 1. A framework for demand and supply players and relationships*

Adapted from Heywood & Kenley (2010) Figure 1.

The research investigates whether a consumption-based demand and supply framework is applicable in the residential building sector; whereby demand stakeholders include both the home purchaser as the ultimate consumer (User) and Volume Builders as the Client. It is imperative to understand stakeholders' roles and relationships in order to develop an appropriate and effective framework to enable innovation towards sustainability.

The research uses semi-structured interviews with the Volume Builders that include process mapping where participants are asked to graphically depict and describe their organisations, roles and responsibilities; contractual, product and customer relationships; and the flow of information and power associations. This shows, on analysis, the various structural relationships in their procurement models and identifies how innovation and change are enabled through the current mechanisms operating in the residential housing industry. This paper is from a research project in progress. Consequently, the model is explained using three revelatory case studies (Yin, 1994) representative of different types of mainstream, Australia-wide Volume Builders. The first participant is classified as a 'Community' Volume Builder where they develop whole communities integrated with housing products, hereafter referred to as VB1. The second is a smaller scale Volume Builder that is a franchisee of a major Volume Builder group that provides single houses for individual land parcels, and is hereafter referred to as VB2. Finally, a smaller Volume Builder (VB3) who specialises in sustainable dwellings described their key drivers and inhibitors in mainstreaming sustainability in their building process. VB3 is an interesting case, because they were a traditional style builder in a small town. However, when the town suddenly underwent substantial growth (mining town – the opening of a new mine and requirements for lots of new housing), the Volume Builders arrived in town. VB3 found themselves without work, so in order to differentiate themselves to win work they began incorporating sustainability initiatives as standard into their homes. This was very successful in their region and they have subsequently expanded Australia-wide with their housing/business model.



## **4. Findings and discussion**

### **4.1 Australian Volume Builders' approaches to home building**

The case study Volume Builders exhibited approaches to home building consistent with the analysis above about the sector's nature. In their relationship with housing consumers, consumers were offered limited choices from standardised options, in effect dictating to consumers what they want and how they want it, whilst providing controlled choice. For example, in the case of VB1, as a consumer, you can choose a dwelling in their development – a three, four or five bedroom home. There may be a choice of facades and internal finishes, however, for the consumer that is where the choice ends. VB1 designs, builds and develops that dwelling without further discussions with the housing consumer. VB2 and VB3's approach is to have a standard set of plans, with options for facades, internal finishes, and other options. However, VB3 as a standard then takes the consumer's selection and ensures that the site selection and the dwelling envelope achieve passive house design standards and maximise opportunities for sustainability and energy efficiency. Whichever approach is used, the Volume Builders provide a standard approach to the provision of various forms of plans, façades, interior features and the like. Essentially this is what would appear to be a wealth of choice, from the purchaser's perspective. Only VB3 actually considers, as a standard in their housing process, the dwelling's siting on the lot and ensuring a high quality, more efficient home. However, if a unique, let alone an innovative home is requested or there are changes to the standard set of plans, this incurs substantial cost to the homeowner, regardless whether it was VB2 or VB3 and in the case of VB1 it was not possible at all. Consequently, the user has limited demand power, and influence is only achieved indirectly through preferential choice of products supplied. There is greater discussion and communication of requests in the case of VB3 and to a lesser extent VB2, whilst no option at all in the case of VB1. VB1 did indicate they do a lot of market analysis and customer surveying to identify what consumers are seeking. However, if consumers are unaware of what could be offered, if they are uneducated how do they know what to direct the Volume Builder to incorporate in such surveys.

### **4.2 Roles and relationships: Demand-side**

With the paucity of end-user capacity to demand change and sustainability, the cases show that the housing consumer (user) is not the only actor in the 'demand' phase of the residential building process. This is clearly expressed by responses from all three Volume Builders, in that they saw their customer as the user who was seeking a finalised product/package in the form of a completed dwelling. This contrasts with traditional theory that the housing consumer is essentially both the user and the client (see for example Boyd & Chinyio, 2006; Love, 2002; Wilkinson & Schofield, 2003). This research supports Tombesi's (2006) classification that the housing consumer is the customer of the Volume Builder and is the end user, choosing a 'known' product from a selection of products which only indirectly affects supply products through preference selection.

This supports this paper's proposal that in current Australian residential building processes the Volume Builder is the actual client. Clients are the initiators of the project (Atkin and Flanagan, 1995). Tombesi (2006) concurs that clients 'prescribe the program, set the characteristics and define the ideal traits of what is yet to be produced' (pp. 277). This is supported in the evidence.

VB1 clearly identifies this role for themselves in the development, designing and production of their homes. They saw themselves as initiators; they clearly define the programme and traits of the development and homes that they produce. VB1 have minimal options allowable beyond colour option selections which align with a profile of choices throughout the dwelling. VB2, due to how they operate within the sector, provide more options and choice to the consumer, however, “the purchaser doesn’t deal with the contractors, we deal with the contractors.” When asked how their organisation operates VB2 drew a diagram very similar to the Figure 1 framework.

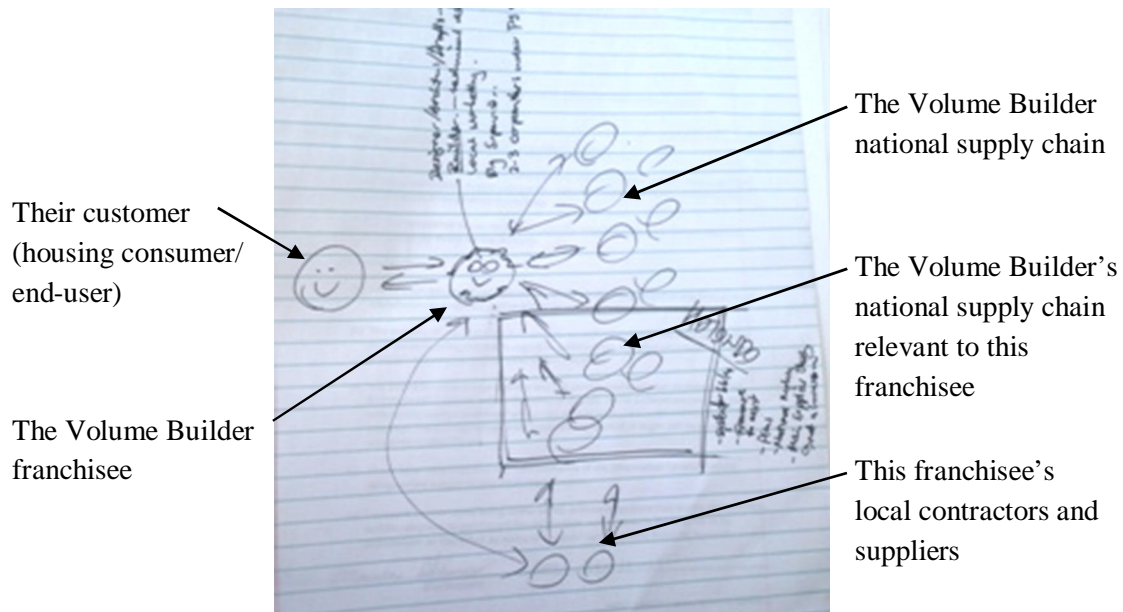


Figure 2 Volume Builder 2's process map

The Volume Builders interviewed agreed that while the consumers sought out their business, they (the Volume Builders) had the ultimate control of the dwelling development, with contracts with various suppliers and contractors which were utilised to build more than one dwelling. Their supply side contracts were large and significant. Whilst VB2, due to its franchise status, had an interesting set up, whereby a number of the material supply contracts (like metal deck roofing, roof tiles; plasterboard) were negotiated and organised by their head office, all contractor type work was undertaken at a local level with contractors and some material suppliers. However, VB2 stated the local engagement was built on long, trusting relationships and consequently they had only one or two key preferred contractors for particular roles within the area; so all work would be done by those contractors. Interestingly, VB3 found their customers tended to be 2<sup>nd</sup> or 3<sup>rd</sup> homebuyers who were generally older, heading for retirement, were fiscally driven and had a rational conscience. Although these homebuyers did not use the term ‘sustainability’ they saw and preferred the services of VB3 because of the realities of cost minimisation in a quality product. As VB3 had difficulties communicating and attracting first home buyers in their markets, it was surmised by VB3 that first home buyers were attracted to the cheapest, base options provided by the general Volume Builders.

Similarly, under consumer theory (European Commission, 2012) Volume Builders were shown to be empowered with the ability to be knowledgeable or to bring the knowledge to drive the market for change, given the right motivators – financial and marketing edges. This was demonstrated by VB3 who in a market with substantial competition, found their edge in the market by differentiating through offering a more sustainable product. They approached their suppliers and contractors and indicated what they wanted to do and were able to negotiate excellent rates which meant that costs of moving to a more sustainable product did not demonstrate significant additional costs. Their existing relationships and contractual agreements meant that VB3 were able to bring sustainability innovation into the new home building process, and due to the collective approach of the demand side (in conjunction with their own consumer demand), VB3 provided the mechanism to drive the change. The common perception of Volume Builders in the sector is mass production, minimal cost, high profits, which makes it challenging to encourage changing their approach. However, as demonstrated by VB3 to gain a competitive edge over competitors' sustainability innovations provided the ability to attract more consumers to their products, whilst providing *“houses that look like, feel like those provided by the other builders, but are more energy efficient”* (VB3).

Consequently, this construes the Volume Builder as the client responsible for demand creation in the supply chain while providing product to the individual user or housing consumer. The Volume Builders' contractual and financial relationships with the supply chain are the demand forces of production requirements. Due to the nature of the Volume Builder's supply chain relationships there are no singular contracts for one house, but an agreement for the mass production of multiple homes. Due to this size the Volume Builder really is the essential 'consumer' and the one who has the control in the building process, as they can dictate to the supply side what they want and how they want it.

### **4.3 Roles and relationships: Supply-side**

As discussed above, Volume Builders are the key demand-side stakeholder, as clearly demonstrated in the Australian residential property market as an oligopoly; where, as oligopolistic players, they behave and move together offering comparable products, limiting and minimising consumer choice. Consistent with that in their relationship with the supply-chain, they wield enormous power in terms of their relationship, requirements and innovation.

The current design and construct theory presumes a singular contractual relationship between the housing consumer and the builder with numerous contracts with the various supply-chain stakeholders (Wilkinson and Schofield, 2003). All three case study participants confirmed this aspect of the contractual relationship; consumers entered into a single contract with the Volume Builders, to produce a single dwelling. However, current practice in the Australian residential property sector differs from the theory, in that Volume Builder supply-chain contracts are generally not for a singular dwelling (project) but for potentially hundreds of dwellings. Again, all Volume Builders confirmed the relationship between themselves and their suppliers and contractors, in that arrangements existed in the building of multiple dwellings. So, the contractual agreement financially is significantly larger overall than the contract between the housing consumer and Volume Builder. Consequently, this transfers the power balance to the demand

side, as the Volume Builders can dictate to an extent their requirements to the supply chain stakeholders. Although Thorpe et al. (2009) suggests innovation from the supply side is limited and the upwards push from it is often met with substantial limitations. This is particularly so in the aspect of knowledge transfer, where it was discovered here that suppliers will tend to approach and display new products to the Volume Builders. However, the engagement with the product was limited, unless the Volume Builder saw a direct reason or purpose for the product or suggestion to be included (VB2). More often, the Volume Builder took the role of initiating the need for innovation and would contact the supply-side stakeholders – be it material suppliers or contractors and seek their advice and whether they could supply and at what price (VB2). VB1 also indicated a similar approach. However, they would approach supply-side stakeholders with a ‘problem’ rather than general requests and innovation would evolve from problem solving rather than directly seeking ‘innovative’ ideas. However, both VB1 and VB2 indicated that if the product quality or price did not satisfy their requirements they did not engage with or utilise the product and would continue seeking appropriate priced or quality services or product. In this case, the Volume Builder can dictate their requirements, be it an innovative solution in the design and construction process, or a sustainability initiative, but it is up to the supply chain to supply the product at a price and quality acceptable to the Volume Builder, otherwise the Volume Builder will choose a different supplier or provider.

#### **4.4 A framework for sustainability innovation**

Recent research shows the Australian home building resists the wide-spread adoption of sustainability innovation for a variety of reasons (Pitt and Sherry 2014). Examples of those reasons can be seen in previous theorisation about the problem, which identified issues primarily with housing consumer-users' ability to demand through willingness to pay for such innovation. Issues have also been identified with the construction supply chain's capacity to 'push up' innovation into more sustainable housing. However, much of this previous work is limited because it examines only part of the system rather than as a whole. This suggests that a new whole-of-system perspective is required, particularly for mass produced housing which makes up a significant proportion of new residential construction in Australia.

This paper adapts a consumption-based demand and supply framework proposed by Heywood and Kenley (2010) to provide a whole-of-system perspective and as a basis for driving wide-spread adoption of sustainability innovation. The case studies tested the framework in the Australian Volume Builder context where the mass production of new housing occurs. On the basis of that testing it can be argued that the model is applicable and that it provides a basis on which to argue for its usefulness in mainstreaming sustainability innovation. It is applicable for several reasons. One reason is that it shows the Volume Builders' traditional theoretical positioning as a supplier of housing. For this study's Volume Builders their housing supply was restricted to standardised designs with limited opportunity for consumer-users to demand other than from a controlled set of options. A second reason is that it shows the supply occurring within a Design and Construct procurement system and a construction supply chain to support that system. In the Volume Builders' construction procurement the traditional assumption in Design and Construct theory of a unique supply chain for each construction contract was varied with

supply-side contracts applying over multiple houses and in VB2's case multiple Volume Builder franchises. A third reason is the framework shows Volume Builders at the central position in the demand-supply system at the overlap between the demand and supply sides, a position that becomes crucial in the innovation argument. In that position the Volume Builders not only supply to consumers but also demand from the supply chain. This makes them the crucial client in the system.

This central position is key, formally or structurally, and also through power dynamics in the Volume Builders' demand-supply arrangements. From this position of knowledgeability and the restricted product offering Volume Builders have a power to shape products supplied to consumer-users. From their contracting position with supply-side stakeholders, generally being small to medium sized operators, they have power over what is demanded from their supply chains. With this demand-supply framework formally showing the whole-of-system relationships and from knowledge of power dynamics it can now be argued that Volume Builders are the place where the drive for sustainability innovation needs to occur. This is in the creation of innovative, truly sustainable housing products to create a latent demand that allows Australian housing consumer-users, with a propensity to pay for perceived lifestyle, to take up a more sustainable lifestyle. It is also the place to demand improved products and construction practices to deliver the innovative, sustainable housing products. This was demonstrated by VB3 who used their power to drive sustainability through the supply chain, overcoming the commonly known barriers for sustainability like: cost, quality of product and quality of installation. Interesting, VB3 indicated that a lot of the efficiencies in the dwelling were resolved through increasing quality standards and requirements, using better materials and careful initial siting and design considerations; meaning minimal costs implications for the housing consumer.

By using this paper's demand-supply framework to change perspective on achieving sustainable new housing there are opportunities for using the power of the oligopoly in mass produced housing to drive widespread market change through the system. Often this has been the basis of past, regulation-driven approaches whereby it is thought that more stringent rules for builders will result in greater amounts of more sustainable housing. The Pitt and Sherry (2014) work show that the regulation-driven approach is not succeeding. A demand-supply approach utilised here suggests a more market-focussed approach could be useful. There is the capacity and ability to drive a more, innovative, sustainable product into the market place without incurring additional cost, providing a product that looks and feels the same as current conventional housing but is significantly more sustainable. The Volume Builders' strong relationships, contractual and financial power over the supply-side stakeholders means that should Volume Builders engage with and take the opportunity to mainstream sustainability initiatives into their housing provisions, the supply chain will then need to respond, which is clearly demonstrated by VB3's experience. The size and power of the Volume Builders means they can enable cost efficient solutions due to contract sizes and volume of houses. This should mean that issues identified by homebuyers, like cost effectiveness and quality of workmanship and product, can be achieved through the actions of the Volume Builders in mainstreaming sustainability.

## 5. Conclusions

This paper examined key stakeholders' roles in mainstreaming sustainability innovation in Australian residential construction – particularly for mass produced housing where Volume Builders dominate to the point of constituting an oligopoly. The demand-supply framework proposed a whole-of-system approach which was confirmed in the case study firms showing Volume Builders occupying a central, powerful, demand position and acting as the 'real' client in driving innovation. From that central position there are also opportunities to innovate and supply more sustainable housing and through their market power and scale to mainstream sustainability in their products offered to their customers.

An ongoing project using practice evidence from Australia provided the basis of this paper. The cases analysed here are revelatory of the phenomenon in Australia and have generalisability from that revelatory capacity. Work is underway to expand the number of cases to provide a larger representative sample of Australian Volume Builders. The framework considered here would also benefit from its use in studies in other countries' new housing supply to see how it holds there as a theory, generally, and for how it assists in mainstreaming sustainability as necessary innovation.

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# Customer roles in a business ecosystem– A case study in health and wellbeing campus

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## Abstract

Business ecosystem refers to a co-evolving, self-organized value constellation where mutually dependent actors create value propositions to diverse set of customers. Ecosystem customers can be characterized as multi-dimensional actors. They take part in the value creation and consume the value that ecosystem provides. This study examines how the ecosystem end customer requirements define the core set of service providers and their relationships in a health and wellbeing campus. An individual service provider's definition of customer may be different than the ecosystem's end customer, especially if the end customer role and involvement into the value creation is not deployed across the ecosystem. Identification of customer value consumption processes and the requirements relevant for the ecosystem value propositions provide a baseline for sustainable ecosystem planning. This study presents how multiple customer roles and logics define the scope of a health and wellbeing built environment campus in its start-up phase. We conducted semi-structured interviews of suitable campus resident candidates to identify the end customer requirements for the case ecosystem service elements. Ecosystem core service providers and their relationships were modelled based on the most relevant requirements. The findings of the study increase knowledge on how diverse actors contribute in different roles to the built environment ecosystem value, and how the customer relationships in the ecosystem can be modelled as tiers in the ecosystem hierarchy. The findings indicate a need to build deeper understanding of value proposal definition, and how the stakeholders' activities are to be aligned towards the end customer value processes. The study outcome emphasizes the importance of the central actor's role as an ecosystem key architect (initiator). Managers can use the findings to align internal activities with the business ecosystem's goals, to identify the ecosystem external drivers and to improve efficiency of the value creation processes.

**Keywords:** Business ecosystem, business in built environment, customer roles, value proposal.



# 1. Introduction

Business ecosystem as a concept to define interacting, self-organized and evolving value networks has different interpretations in academic discussion. Positioning the ecosystem concept with other value constellation models is not unambiguous. Ecosystems are not strictly defined, they are not systematically managed and they have multiple business and non-business actors either directly or indirectly impacting the value creation (Moore 1993; Iansiti & Levien 2004). Ecosystems such as Apple's developer platform emerge in fruitful conditions around new technologies or business models. They provide opportunities for business model adaptations and new business emergence (Moore 1998; Gawer & Cusumano 2014). Their emergence can be facilitated, but as self-organizing entities the evolution is organic based on actors' interdependencies, complementing capabilities and abilities to adapt to changes through innovations (Corallo 2007).

Value of business ecosystem is service driven as all actors – including the end customers – contribute actively to value creation and consumption (Vargo & Lusch 2004). Interdependencies between the actors involve customer relationships (Moore 1998; Corallo 2007). System level value of the ecosystem is defined by the end customer whose requirements and processes drive the value creation and consumption (Eichentopf et al. 2011). Service and customer dominant logic concepts illustrate how the customer internal processes determine their perception of the value (Vargo & Lusch 2004; Hakanen & Jaakkola 2012).

This study aims to illustrate business ecosystem as a customer centric value constellation. Modelling the ecosystem through the customer requirements is expected to identify different levels of customer roles in the ecosystem as the actors have different customers based on their position in the ecosystem's value process. The end customers' requirements define the system level value proposals and actors derive their requirements and relationship types by reflecting the requirements against their business models.

Built environment projects can be seen as bases for ecosystems where service providers co-operate to provide benefits for the end customers, the built environment residents. Value is created as joint activity when the service providers have complementing capabilities to consolidate unique offerings (Pinho & Fisk 2014; Frels et al. 2003). This requires transparency on residents' needs and requirements. Understanding the customer role hierarchy in a very early phase of a business ecosystem has positive contribution for efficient ecosystem planning (Aapaoja et al. 2013). Central actors who host ecosystems, or projects implementing them, can utilize this study findings as an actor planning framework. Involving the core service providers and complementing stakeholders through a customer tier based model improves efficiency for the campus design as a flexible and sustainable built environment that can support diverse set of people with health and wellbeing services.

The main aim of this study is to enhance understanding on stakeholders and their roles in ecosystems. For this aim we have set the following research questions: *Who are the service providers that should be involved into the campus ecosystem and how the customer relationships between residents and service providers form the ecosystem.* At first we review literature on

business ecosystems, customer role in it and value for customer to outline how customer requirements can define an ecosystem. We identify and interview suitable resident candidates to determine most relevant requirements and their service providers. As a result we conceptualize ecosystem modelling from customer relationship perspective and contribute to business ecosystem application field and positioning in context of other network descriptions.

## **2. Business ecosystem customer definition**

Business ecosystems as evolving networks consist of multiple actors. Interactions between actors are based on customer relationships where value proposals are transferred and consumed. The customer relationship type changes based on the actor position in the ecosystem. This literature review introduces key characteristics of business ecosystem concept, customer role in ecosystem and how value proposals are defined and transferred through customer relationships.

### **2.1 Key characteristics of a business ecosystem**

Ecosystem concept was introduced into business by James F. Moore (1993) in his seminal paper “Predators or Prey”. Business ecosystem seeks analogies from biological ecosystem to explain complex phenomenon and value constellations. For example a value chain of an ecosystem can be modelled as a supplier-customer network like a food web in biology. (Moore 1993; Corallo et al. 2007)

Business ecosystem is an extended system of mutually impacting and evolving organizations. Indefinite timing, dependencies between actors and self-organization extend the ecosystem to be a wider concept than value constellation models like business networks or value chains (Iansiti & Levien 2004; Moore 1998). Ecosystem actors interact with one another either directly or indirectly to produce goods and services. Ecosystem actors share a common goal and are dependent on each other in contributing towards it (Gossain & Kandiah 1998). Successful business ecosystems have novel end user value, economies of scale, continuing innovation and willingness to invest to expand with allies. Ecosystem boundaries are not explicitly determined and the contributing parties change over time (Moore 1998).

Ecosystems as interdependent actor networks operate on service dominant logic, where service is defined as application of specialized competences through deeds, processes and performances for the benefit of the acting entity or another entity within the scope of the ecosystem (Vargo & Lusch 2004). Sharing of knowledge, focus on system level customer experience and managing interfaces with stakeholders as continuous processes are elements from the service dominant logic that support the business ecosystem concept (Moore 1993, Vargo & Lusch 2004).

## **2.2 Customer role in business ecosystem**

Each ecosystem actor operates in a customer role through the relationships they possess with each other. Customers that consume the system level value proposition and participate into creation of it are considered as the ecosystem end customers. Pinho & Fisk (2014) identified three types of interdependencies between ecosystem actors: dynamic role interdependency (roles change), temporal interdependency (interactions occur sequentially) and self-interdependency (value creation depends on actor's own actions). The distinctiveness and nature of interdependency has implications into designing of actor roles in the ecosystem.

Success of a business ecosystem is defined by its capability to deliver unique value for the end customer. End customer participates into the value creation through personalized interactions with the ecosystem service providers. End customer feedback and its deployment over the ecosystem drive co-evolution. Co-evolution is essentially about triggers from the end customer that travel through the population and cause new triggers to be sent. (Hakanen & Jaakkola 2012; Prahalad & Ramaswamy 2004).

Ecosystem actors need to understand how active role the end customer plays in the value creation and consumption. They are connected, informed and empowered to influence the services they utilize, as the services are often highly complex consisting of interaction, exchange and performance. The ecosystem end customers should not be treated as passive consumers of the products the supplier provides. (Prahalad & Ramaswamy 2004; Wu 2008)

Business ecosystem can be visualized through its actors. The actors with most dense relationship network lead the ecosystem operations as value integrating actors. They enjoy both efficiency and control benefits as they hold positions between the actors that are not directly linked. In case these actors are removed, the ecosystem would be dissolved into disconnected subnetworks. Through visualization the actors can make an assessment on how to preserve, protect or transform their position through potential alliances and strategic partnerships (Lacoste 2016). Visualization can also provide an immersive environment for what-if scenarios as well as support for strategic and operative decisions. (Basoule 2009; Iansiti & Levien 2004)

## **2.3 Value proposals with customers drive success**

Involving end customers into the value proposal definition make them part of a reciprocal process towards equitable exchange (Vargo & Lusch 2004; Payne et al. 2005; Ballantyne et al. 2011). In business ecosystems the actors' relationships have multiple dimensions integrating the services for richer value propositions (Iansiti & Levien 2004). The service dominant logic emphasizes the potential of joint value proposal creation and knowledge sharing in a customer relationship. (Ballantyne 2006).

Analysis of customer relationships in a business ecosystem should be extended to cover the multidimensional dependencies between ecosystem actors. Understanding the dynamics will often unleash a considerable potential for co-learning in the ecosystem that is critical for sustainable co-evolution (Ballantyne et al. 2011). Nätti et al. (2014) define how the intermediary role in triadic relationship contribute to the value co-creation. In business ecosystem planning it is important to understand the relationships and processes where an intermediary has significant contribution either through making promises or acting on behalf of the service provider. (Nätti et al. 2014)

Vargo and Lusch (2004) state that the specialized skills and knowledge are fundamental exchange units in service dominant logic. This is similar to Iansiti and Levien (2004) view on how the ecosystem actors bring specialized resources and competences to the ecosystem. Ballantyne (2006) challenge the unique knowledge or resource assets as critical exchange element by classifying those merely as enablers. The actual transaction is built by the interfacing actors on top of the enablers brought in by the parties. (Ballantyne 2006). The interaction needs to be spontaneous, collaborative and dialogical in order to set up a value processes of a prospering business ecosystem.

Effectiveness of business ecosystem's value processes depends on how much value can be jointly created for end customers. Major contributor for the effectiveness comes from the ability of ecosystem actors to select and exploit opportunities with highest potential to improve customers' satisfaction, business revenue and new competitive advantages (Romero & Molina 2011). Both ecosystem internal and external relationships need to support long term profitability of the ecosystem and adaptability to changes (Lacoste 2016).

Ecosystem actors need to change their culture to utilize innovation of other actors, especially if they have successful track record of internal innovation (West & Bogers 2014). In business ecosystems the actors need integrative competences to link external innovations into their value propositions. Actors should develop the network of compatible external competences of other actors in multiple dimensions (Frels et al. 2003). In order to create effective value proposals, the ecosystem actors need to create fit not only between the proposal and the end customer but also between the goals, preferences and resources of the other service providers (Hakanen & Jaakkola 2012).

Payne et al. (2008) define customer value creation as an outside-in process. It starts from understanding the customer's own value processes (outside) and aims to define a value proposition that complements and enriches the customer perceived value (in). The process is cross-functional requiring alignment between the actors. By developing early concepts of the value proposals the ecosystem actors can test the feasibilities of co-creation options already in planning phase. (Shafer et al. 2005; Eichentopf et al. 2011).

Committed interplay between the actors is a prerequisite for ecosystem success. Actors can introduce a value proposal, but customers need to be involved into further development of it (Romero & Molina 2011). The customers commit to the value proposal when they understand the

benefits and are able to utilize those in their internal processes (Frow et al. 2007). Customers appreciate being able to influence and control the value process even if they do not use the outcome (Eichentopf et al. 2011).

Customer is more involved in service based value proposals where the value creation and consumption overlap and take place at the same time. Chakraborty and Kaynak (2014) summarize the service characteristics impacting customer involvement as ease of service generation, value of service and ease of assuring service quality. Complexity of the service, relevancy of it to the customer and frequency of the service consumption are some attributes used to assess the service characteristics (Chakraborty & Kaynak 2014).

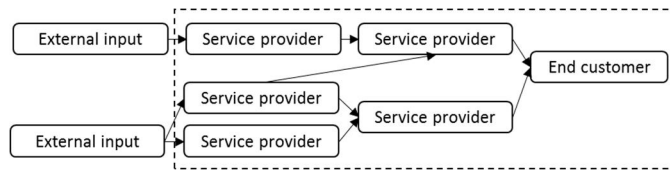
## **2.4 Summary: Customer relationships make an ecosystem**

A business ecosystem can be modelled through the actors' customer relationships. Based on the customer requirements the joint value proposals can be defined enabling mapping of the service providers as a value creation network originating from the end customer. End customers should be integrated to the ecosystem value processes in order to understand their true preferences. In a dynamic ecosystem the actors are interdependent in value creation. They interface with internal and external stakeholders through customer relationships forming a hierarchical structure with both business and non-business driven service providers and active end customers.

## **3. Health and wellbeing campus core service providers**

Customer relationships in a business ecosystem were illustrated with a single built environment project case study. The case study subject was a health and wellbeing campus 'Health City Oulu'. Campus is in planning phase in Oulu, Finland. The campus will consist of ten apartment houses and a service center for the campus residents. The concept introduces a novel housing set-up in Oulu, where the health and wellbeing services support physical activity and ease the everyday life. The Health City concept owner's target is to have wellbeing and everyday life supporting service providers -such as kindergarten, training gym or grocery store - operating on the campus and that the service providers would provide together value proposals not possible in other environments.

The campus as a business ecosystem consists of resident candidates - potential end customers- and service providers. Service providers integrating the value proposals have internal customer roles in value process. They also gather inputs outside ecosystem. Customer relationships as ecosystem value process is illustrated in figure 1.



*Figure 1. Customer relationships as ecosystem value process*

Resident candidates' insights on how they would like to live on the campus and what services they wish to use provide insights about value proposal and related customer relationship types. Figure 1 presents how value proposals can be traced back in the ecosystem from end customer. Modelling the ecosystem based on the customer relationship types support efficient ecosystem planning as it enables suitable service provider selection and complementary capability definition (Romero & Molina 2011).

The campus target is to have residents from all stages of life for a rich environment and for innovative value propositions. Diversity is one of the key characteristics of a sustainable business ecosystem (Iansiti & Levien 2004). The campus fosters interactions amongst the service providers and end customers integrating the actors into mutually benefitting value constellation that protects the ecosystem against external impacts and competition (Gossain & Kandiah 1998).

Public data such as reports and documents about living trends in Finland and Oulu and statistical data about Oulu inhabitants was used to determine suitable campus resident candidates. Public data sources used are presented in table 1. To determine their requirements for the service providers we interviewed 50 persons as the resident candidates to hear how they would like to live on the planned campus and what types of services they would wish to consume. Profiles of interviewed persons are presented in figure 2. The interviews provided information about the service element requirements and relates providers. The interviews were conducted in June-October 2015 in Oulu as semi-structured interviews.

*Table 1. Public data sources used to identify resident candidates*

Name	Source	Published
Citizen barometer of Oulu 2011	City of Oulu, Finland	2011
Commercial report on Huukkavaara Oulu suburb	City of Oulu, Finland	2007
Constructors role in residential area branding	Jenna Taajamo, University of Tampere, Msc. Thesis	2014
Future of senior housing based on living preferences	School of Arts, Future Home Institute, Finland	2005
Health and wellbeing campus initiative - call for partners	City of Järvenpää, Finland	2014
Home in downtown - City center as living environment for families with small children - Stockholm and Helsinki	Johanna Lilius, University of Helsinki, Msc. Thesis	2008
Living environment preferences - Resident views on environment, housing and services in different life stages	Consumer research center Finland	2008
Living preferences, opportunities and life cycle	Anneli Junto, Ekoelias seminar	2009
Predicting the future of housing	Ministry of Environment, Finland	2007
Resident driven housing development	Matti Kuronen, YIT construction company, Finland	2009
Service housing as an option for senior citizens - questionnaire and interview	Ministry of Environment, Finland	2005
Sustainable community structure and living environment	Communal research and education center, Finland	2010
Townplan report (Toppila, Tuira, project 100169)	City of Oulu, Finland	2014
Update on commercial report on Huukkavaara Oulu suburb	Colliers international Oy	2013

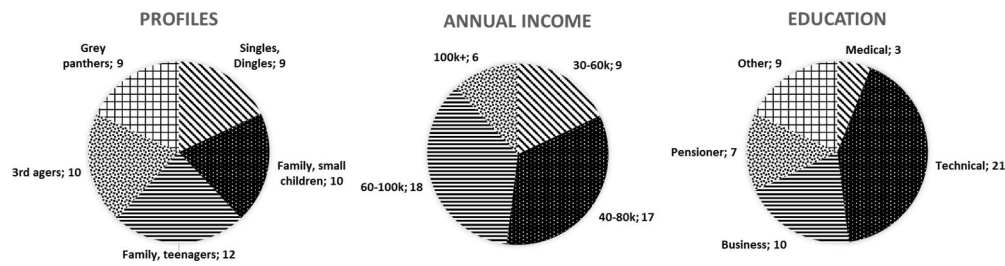


Figure 2. Profiles of interviewed persons

In the semi-structured interviews we asked about the service elements for the campus ecosystem the interviewees would see contributing most to the fluent everyday life and physical wellbeing. Furthermore we asked them to prioritize three of them. Figure 3 presents the service elements the customers preferred to have on the campus.

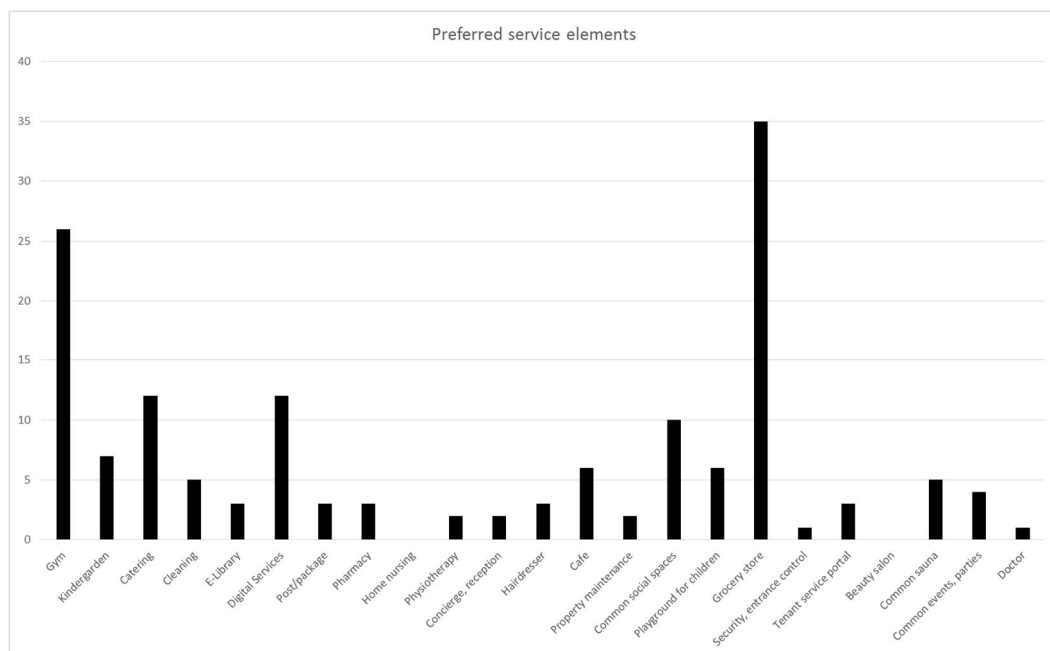


Figure 3. Preferred Health City Oulu service elements.

The interviews were recorded and analysed. Training gym, grocery store, catering and digital services were considered as the most valuable elements common to all profiles. We consolidated these elements to core service providers together with the campus concept owner in an iterative process. The process included several meetings to filter appropriate content and observations from the interview data. Consolidation of the service elements to core service providers follows the business ecosystem (Moore 1998; Iansiti & Levien 2004) and customer dominant logic (Hakanen

& Jaakkola 2012; Pinho & Fisk 2014) characteristics where integration of the service value proposals define ecosystem key value elements.

Based on the consolidation we formulated four core service providers as service element integrating ecosystem actors: *Grocery Store*, *Training Gym*, *Senior services* and *Kindergarten*. They have capabilities to integrate, deliver and iterate the ecosystem value proposals to the end customers. They involve other service providers to the value creation processes. Core service providers act as intermediators (Nätti et al. 2014) in the ecosystem facilitating the joint value creation. For example Kindergarten could offer catering services on the campus while providing meals for the children as part of day care.

## 4. Customer tiers in a business ecosystem

Aapaioja et al. (2013) presented a tier based model to categorize a built environment project stakeholders. Consolidation of the core service providers and joint value proposals in this study enable designing a tier based model for ecosystem customer relationships as hierarchical layers. The core service providers form the inner circle of a campus ecosystem hierarchy around the end customer. Their interdependency with the end customer is dynamic and temporary (Pinho & Fisk 2014). As the value proposal creation-consumption is a unique experience in service dominant logic (Vargo & Lusch 2004) the self-interdependency also plays an important role in defining how the core service providers integrate the value proposals.

We present a business ecosystem customer tiers in figure 4 with selected service providers from the case study results. The model elaborates the differences between the customer roles in the value process and how the relationships are formed across the tiers. Role of the service provider for the end customer value proposal based on service characteristics (Chakroborty & Kaynak 2014) and the types of interdependencies between other actors (Pinho & Fisk 2014) determine their tier.

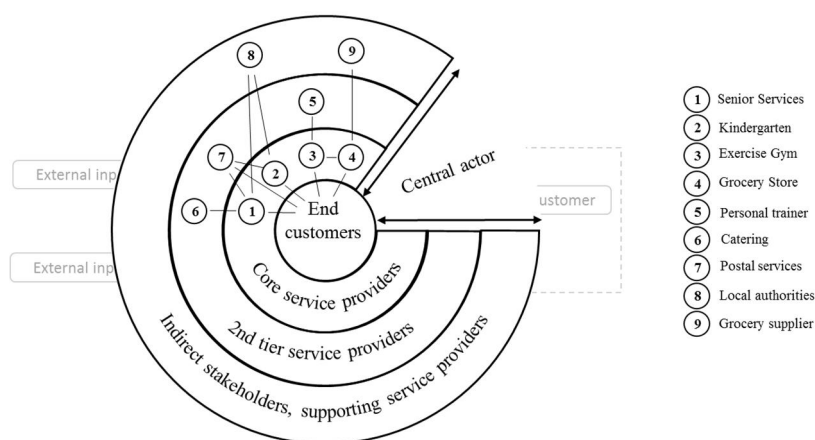


Figure 4. Business ecosystem customer tiers on ecosystem value process



**End customers** are positioned to the center due to their focal role in ecosystem value definition. They consume the value the campus ecosystem creates and set the requirements for the service providers.

**Core service providers** in the case are Senior Services, Kindergarden, Exercise Gym and Grocery Store. They are located physically in the campus. They master the system level value proposals and encounter process with the end customers. They deliver the ecosystem value proposals to the end customers in most cases.

**2<sup>nd</sup> tier service providers** include multiple service providers either complementing the core service providers' capabilities or interfacing directly with the end customers with own value proposals. Examples of these are personal trainer, catering and postal services. 2<sup>nd</sup> tier service providers have core service providers as their key customers. They can also operate temporarily on the campus.

**Indirect stakeholders, supporting service providers** are not integrated into the campus ecosystem but temporarily, or in a specific manner, influence the campus ecosystem. Their impact is through the service providers operating within the ecosystem. Actors in this category are for example local authorities or grocery supplier. These actors may also interact with other ecosystems.

**Central actor** orchestrates the customer relationships via the interfaces between the tiers. The central actor facilitates the ecosystem evolution by providing rules and operational practices for actors. Campus concept owner operates as the central actor in the studied case. In the start-up phase the central actor can set up the baseline for the customer relationships by involving the key end customers and core service providers in to the planning. Once operational, central actor takes a facilitating role to support the ecosystem as a self-organizing entity.

## 5. Discussion

We identified different ecosystem customer relationships with the case study 'Health City Oulu'. The customer tier model presents how the ecosystem actors can be described as hierarchical layers on top of ecosystem value process. The core service providers are the value integrators. Actors on the other tiers consider the inner circle actors as the customers of their own value proposals, or are being facilitated by them. These findings support the multifaceted customer role as an ecosystem defining characteristic presented by Moore (1993, 1998), Iansiti and Levien (2004) and Gossain and Kandiah (1998).

Different types of interdependencies (Pinho & Fisk 2014) impact how the tiers of the ecosystem customer relationships are formed. Dynamics of both value proposals and involved actors make customer tier model a dynamic concept applicable to certain ecosystem phase. Central actors of life cycle built environment projects would benefit from tier model as a project scoping tool.

Generalizability of the customer relationships roles would benefit from further research. The key contribution of this single case study is a conceptual model on the customer relationship tiers and how the tiers describe the campus ecosystem. Method on how to identify core service providers applies in this study to a campus ecosystem planning. Once it is operational, a similar study could bring up different actors as the residents would base their priorities on experienced value instead of expected. Furthermore, a research on o phase would provide insights about how external inputs impact the ecosystem.

For the business ecosystem research this study introduces a novel conceptual model that follows the Payne et al. (2008) value creation process driven by customer internal processes and requirements. End customer as the central point expands the role of technologies or innovations as the driving forces for business ecosystems (Moore 1993; Gawer & Cusumano 2014). Modelling the ecosystem from the end customer perspective unveils the ecosystem value integration and control points. Research on customer centric ecosystem structures and their evolution would complement the knowledge on ecosystem drivers. Such research could also identify how the business and information transactions in the ecosystem may be enhanced.

The customer tier model describes the central actor as the orchestrator of the interfaces with limited substance value contribution. Central actor defines the strategic targets for the campus ecosystem and facilitates the ecosystem relationships. Central actor in the start-up phase involves the core service providers so that the promise given by the campus to the resident candidates can be fulfilled. Development of the central actor role would also be another subject of further research on built environment projects and ecosystems.

## **6. Conclusions**

This case study research responds to the defined questions about core service provider identification and customer relationships. Identification of the ecosystem core service providers is an essential task in a built environment project as their contribution to the planning has significant importance to the ecosystem's successful start. Complementary capabilities of the core services providers integrate them with the campus end customers into joint value creation process.

Business ecosystem and service dominant logic concepts extend the dimensions of how ecosystem central actors or built environment project managers could approach the challenges related to resident candidates' requirement identification and key stakeholder management. Positioning the end customer into the center of the actor definition process, and categorizing the actors into tiers by their customer relationships define a customer centric tier model for the ecosystem. This model contributes on its part to streamline the ongoing discussion about complexity of a business ecosystem as a concept in context of other value constellations.

The customer tier model can be utilized to define the needed actors for initial value definition. In Health City Oulu context the initial value definition should be conducted before the campus

project enters building phase. This would ensure that the apartment houses and service center provide a flexible and sustainable environment for the health and wellbeing service ecosystem to emerge once the campus becomes operational. Value definition as part of the project planning aligns the ecosystem start-up activities with its strategic targets.

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# Development of students' multidisciplinary collaboration skills by simulation of the design process

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## Abstract

This paper examines the application of multidisciplinary collaborative learning in higher civil engineering education. The changes in the construction sector are setting new challenges for the higher education of the construction sector. The construction projects have become more and more complex involving numerous stakeholders. This is setting high requirements for multidisciplinary collaboration skills. Present higher civil engineering education does not develop good enough collaboration skills for those students. The first aim of the study is to present a practical model how to implement collaborative learning within course named "Simulation of building design process" with a particular attention towards multidisciplinary involvement. The course has been implemented at the Tampere University of Technology in Finland since 2006. The applied learning method has features from project-based learning, progressive inquiry learning and dialogical approach to learning. The course is implemented through the practice of design meetings, which simulate the actual design meetings. The participating students from different disciplines form a design group. Students' task is designing a building for the predefined need. Each student has a specific role meeting his/her major subject of studies. The second aim of the paper is to analyse how students have perceived the course. The empirical data consists of the feedback by students from the 2009 to 2015 courses. According to feedback students have perceived that collaborative learning has deepened their knowledge on a building design process and their collaboration skills have improved during the course. The course has been found motivating and the student-centric nature of it caused by students' possibility to affect on the content of the course and their responsibility of their own learning. The third aim of the study is to discuss the developing of students' multidisciplinary collaboration skills in higher civil engineering education. The course has shown that with new learning methods can make learning more context-oriented and enhance students' motivation, which usually affects positively students' learning. The results of this case study suggest the potential of using collaborative learning in higher civil engineering education.

**Keywords:** collaboration, multidisciplinary, engineering education, collaborative learning, design process

# **1. Introduction**

The construction sector and the whole society have faced significant changes in recent years. These changes are setting new challenges for the higher education of the construction sector. The construction projects are more and more complex involving numerous stakeholders. This is setting high requirements for multidisciplinary collaboration skills. The engineers for the current and coming requirements need to be equipped with better skills and new capabilities for sharing expertise, collaboration and project management.

Literature review by Salmisto (2013) reveals that several researchers have suggested that higher civil engineering education does not develop good enough collaboration skills for those students. Many previous studies emphasise the importance of the multidisciplinary and collaboration skills in engineering education. Learning in the universities in question should be more student-centric and develop students' ability to think independently and collaboratively. This paper is about a collaborative learning in higher civil engineering education with a particular attention towards multidisciplinary involvement. The case study incorporated examines the application of multidisciplinary collaborative learning within course named "Simulation of building design process". The aim of this research is threefold. The first aim is to present a practical model how to implement the multidisciplinary collaborative course design. The second goal is to evaluate how students have found the multidisciplinary collaborative course. The empirical data consists of the feedback by students from the 2009 to 2015 courses. The third aim is to analyze how to develop students' multidisciplinary collaboration skills in higher civil engineering education.

## **2. Theoretical framework**

### **2.1 Collaborative learning**

According to Vygotsky (1978) social aspect is distinctive in learning. Students may achieve higher quality learning outcomes through social interaction with peers and between teachers and students. This Vygotsky's point of view is a basis of the collaborative learning. Dillenbourg (1999) define the collaborative learning, as its broadest definition, as follows: "Collaborative learning is a situation in which two or more people learn or attempt to learn something together". He argues that this is not enough satisfactory definition, because it does not define exactly what collaborative and learning means in that context. Helle et al. (2010) argue that collaborative learning is something where students solve a problem together. According to Dillenbourg (1999) collaborative learning itself is not a method. It is more the approach to teaching and learning to achieve high quality learning and meaningful learning processes. In high quality learning, students' motivation and engagement to learning are important aspects (Lonka & Ketonen 2012). Barkley et al. (2014) argue that the strength of the collaborative learning is, that it engages students of different backgrounds to work together actively for the shared aims. Because of this, collaborative learning is an excellent approach for multidisciplinary course design.

## **2.2 Case-based, progressive inquiry and trialogical learning**

The applied learning method, to implement collaborative course design, has features from many learning methods. The basis of the course is the project-based learning, but course has features also from the progressive inquiry method and the trialogical approach to learning. Thomas (2000) defines project-based learning as a learning model that organise learning around projects. In project-based learning students engage in real life situations and solve the real and meaningful problems. Construction is principally project based activities. Therefore the project-based learning creates a good platform to implement learning which based on the real working life problems of the construction projects. In a project-based course, that has been carried out appropriate way, the students can participate in authentic practices and train skills needed in real projects (Helle et al. 2010). Activities could be similar that professionals of the discipline do in real life. Many researchers (Grant 2002; Helle et al. 2010; Thomas 2000) argue that in previous studies have presented various models of the project-based learning, thus there is not clear and exact definition about project-based learning. With qualitative literature review, Helle et al. (2010) have defined five distinctive features of project-based learning: 1) problem orientation, 2) constructing a concrete artefact, 3) the learner control of the learning process, 4) contextualisation of learning, and 5) potential for using and creating multiple forms of representation. Usually, the aim of the project-based learning is to collaboratively construct a shared outcome (Helle et al. 2010).

The method, which have adapted in our course design, also has the features of the progressive inquiry and trialogical approach to learning. Progressive inquiry learning is a pedagogical model based on the theory of knowledge building. It is designed to support typical data acquisition by the specialist and emphasises the activity of the learner and the impact of co-operation in a shared research project and the creation of new knowledge. (Hakkarainen et al. 1999.) The similarity of the project-based and progressive inquiry learning is questions, which direct students' learning process. In project-based learning guiding or driving questions creates a platform for the inquiry of the project team (Grant 2002; Larmer & Mergendoller 2010; Thomas 2000). The basic idea of the progressive inquiry is that the students themselves define meaningful research questions and their task during the learning process (Hakkarainen et al. 1999). Therefore the difference between progressive inquiry and traditional project-based learning is particularly in the presenting of questions and research problems. In traditional project-based learning the tasks and problems are given and students do not define research problems. Also Helle et al. (2010) have found similarities between project-based learning and Bereiter's model of knowledge building (see Bereiter 2002), which is a basis of progressive inquiry. The objective of progressive inquiry is to organise teaching so that there is room for students' questions and the research approach is possible (Hakkarainen et al. 1999). Inquiry oriented working is emphasising also in project-based learning (Grant 2002; Helle et al. 2010; Larmer & Mergendoller 2010).

The progressive inquiry method has been further developed towards the trialogical approach to learning where the learning process is more context-oriented. The purpose is to integrate progressive inquiry and real working life context. The trialogical approach to learning based on a knowledge creation metaphor, which Paavola and Hakkarainen (2005) have been identified by

analysing three models of innovative knowledge communities: Nonaka and Takeuchi's model of knowledge creation, Engeström's model of expansive learning, and Bereiter's model of knowledge building. According to Paavola and Hakkarainen (2005) the trialogical approach to learning concentrates on the interaction through the common objects of activity and, also between people and environment. They define the trialogical approach as 'Learning is a process of knowledge creation which concentrates on mediated processes where common objects of activity are developed collaboratively.' The mediated processes of knowledge creation have become vital in our knowledge-based society (Paavola, Lipponen & Hakkarainen 2004).

## **2.3 Multidisciplinary collaboration skills in building process**

Building project organizations are usually directed and governed by contractual arrangements. Stakeholders in cooperation and their specialist have well-established roles, relating mandates, assignments, contractual duties and payments. (Kähkönen et al., 2013). Plain formal project organizations can be rigid and produce constraints that make difficult or almost impossible value-adding co-operation and communication. Unfortunately still the movement toward more cooperative relationships is hindered by the traditional type of procurement that encourages competition rather than cooperation (Cheung 2003). This is unfortunate since the closer cooperation is needed.

According to several researchers, collaboration is not an option, it is necessity. The report by Egan (2002) recommended that process and team integration as a key driver of change necessary for the industry to become more successful. Also Latham (1994) and Bourn (2000) have challenged the industry to move away from its traditional practices towards more collaborative and integrated approaches. Kusiak and Wang (1993) presents that collaborative working is primary if design and construction teams are to address the entire lifecycle of the construction product and take account of not only primary functionality but also productivity, buildability, serviceability and even recyclability. Sanvido et al. (1992) found seven success factors for construction projects in their study. Four of them have found to be critical. Three out of four critical factors are related to collaboration. Egan (1998) reported five key drivers for improving the quality and efficiency of UK construction. Collaboration is one of them. Chen et al. (2012) reported four factors which have significant influence on the success of construction partnering. Collaboration is one of the four factors. Moore and Dainty (1999) presented that a successful construction project delivery and the performance depend on the integration of knowledge and experience of different stakeholders.

## **3. Methodology**

### **3.1 Sample and analyses**

The subject of this case study, "Simulation of building design process" -course has been implemented since 2006. The course design is based on the key principles of the collaborative learning. The empirical research data of the study consist of the feedback by the students from 2009 to 2015, altogether from six implementations of the course. The feedback was collected

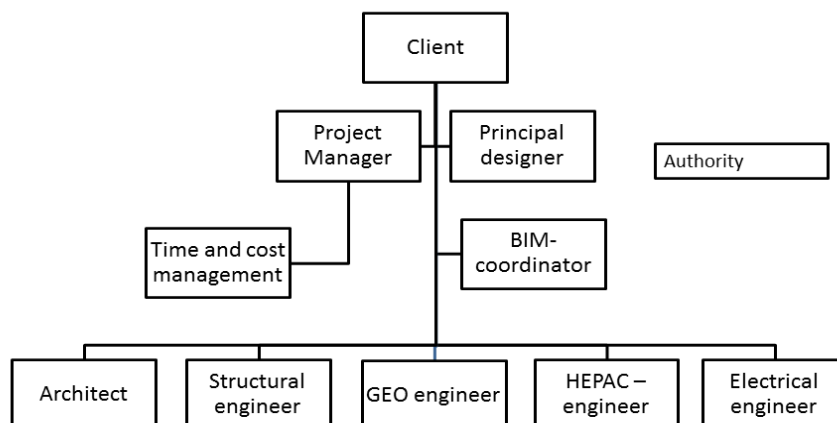


during the last learning event of the course. Students who worked in the same role during the course have given shared feedback. Altogether 35 different feedbacks were available and were analysed in this study. The feedbacks were in written form. It has been asked for the students to write down what succeeded in the course and what should be developed. Each student groups have also presented the feedback during the last learning event of the course to the teachers and other students. The written feedbacks were analysed using inductive content analysis, which involves a process of identifying and classifying data without any theoretical assumption (Schilling 2006). First, the data was collected into the same file and was reduced to the form which is suitable for the further analyses. After that, the data were coded based on expressions which often appeared and were grouped based on the coding. With coding and grouping, were found how students have perceived the course. From the data of each group were searched the original expressions which illustrate well students' perceptions. In addition were counted, how many expressions were included in each group.

### 3.2 Application of multidisciplinary collaborative learning

The first objective of this paper is to present a practical model how to implement the multidisciplinary collaborative course design. The Simulation of the building design process course has been implemented since 2006. For this course the participating students from different disciplines form a design group which consists of the students from architecture, structural engineering, earth and foundation structures, HPAC –engineering, electrical engineering, and construction management and economics (Figure 1). Students' task is designing a building for the predefined need. Each student has a specific role meeting his/her major subject of studies. The course is implemented through the practice of design meetings, which simulate the actual design meetings. The teachers act as observers and provide feedback. However, the preparations of the meetings and their realizations are entirely on students' responsibility. Between the design meetings, students carry out tasks and arrange smaller meetings according to their roles.

*Figure 1: The students' roles and organisation of the course*



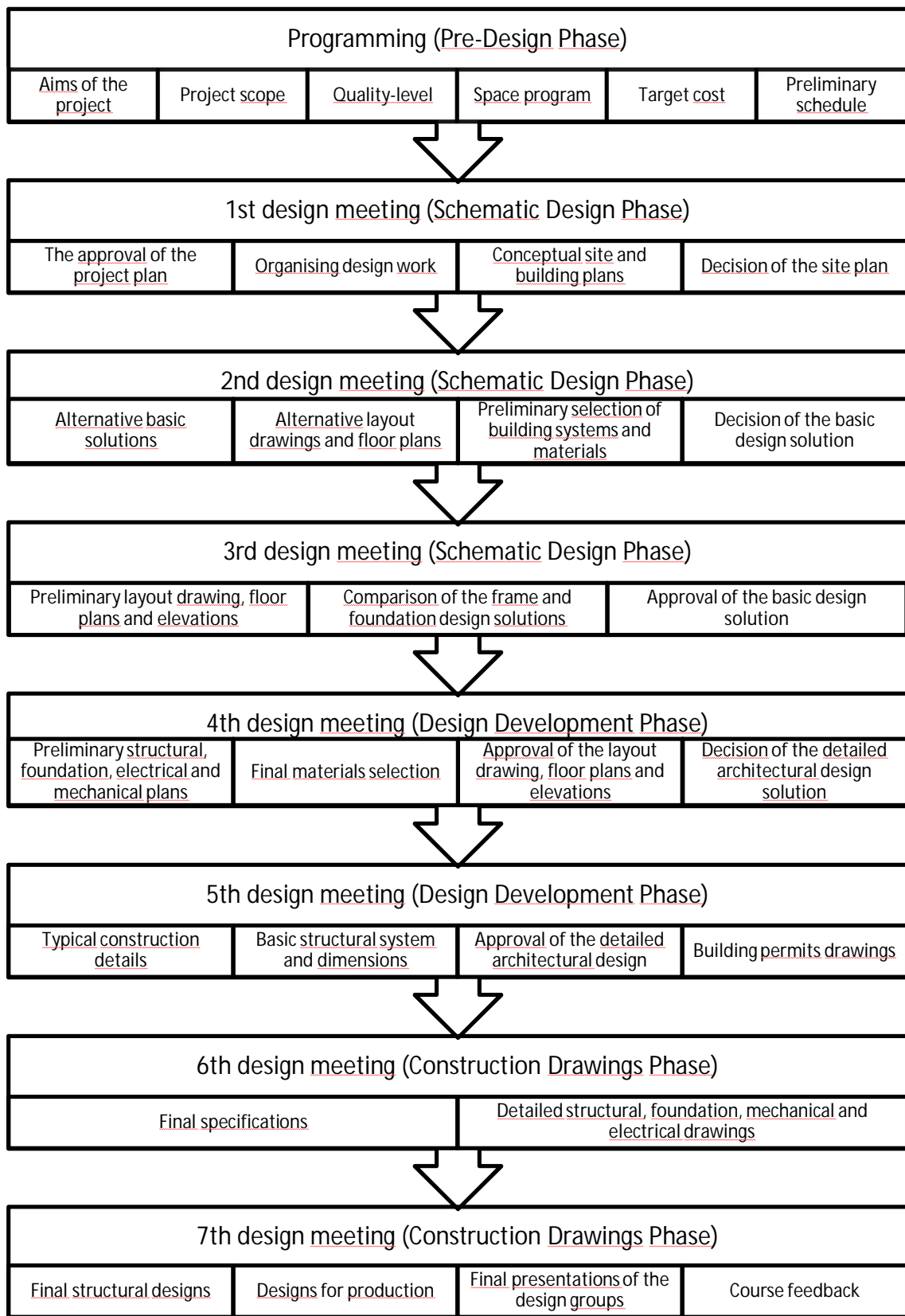


Figure 2: The design process and the progress of the course

The course design differs from the traditional teaching methods at the universities of technology. Often, the courses consist of lectures, assignments and an exam. Assignments are usually predefined by the teachers and have precise guidelines on how the exercise should do. In this course, there are no lectures and exam. Also the starting point of the design process is quite open and unlimited. The students have to define their own task by themselves. Therefore, the course has features from project-based learning, but also from the progressive inquiry learning method and the trialogical approach to learning.



*Figure 3: An example of BIM-based design solution*

The progress of the course is intended to simulate the real life design process as well as possible. Still, there are some things which differ from the actual design process, because the learning aims of the course. For example, the student who acts as authority participates the design meetings and there is not really the briefing phase. At the beginning of the course, each student set personal goals and define their own tasks meeting his/her role. The course starts from the programming phase. The type and approximate size of the building and the site has given to the students for the starting point of the design process. The first task of the students is to make a project plan where they set the goals of the project. They for example set project scope, quality level, a room program, target cost and a preliminary schedule of the project. The actual design begins with a schematic design phase, where students define the basic solution and concept of the building. After the schematic phase, it starts the design development phase. Students design the final solution and create building permit drawings as an outcome of the design development phase. The final design phase is a construction drawings phase, where students create final structural designs and designs for production. The progress and the outcomes of the course differ a little every year, but in Figure 2 is described the suggestive progress of the course. The course took about seven to eight months. The course begins in September and continues till April. The design meetings are arranged approximately every 3-4 weeks. Usually, the course consists of 7-8 design meetings. Recently, students' design process had been based mainly on a BIM-based design (see Figure 3).

## 4. Results

### 4.1 Students' perceptions of the course design

The second aim of the study is to evaluate how the students have found the multidisciplinary collaborative course. The responses to questions, what succeeded in the course and, what should be developed (Table1), shows that students have found collaboration between students and the development of understanding the design process as the best parts of the course. According to feedback, the most significant improvements needs are in the role related guidance and the instructions of the course. In Table1 is presented the results of the content analyses. It shows how many times the subject was mentioned in feedbacks. The subjects, that were mentioned more than five times, are listed.

*Table 1: The grouped feedback responses by the student groups.*

What succeeded in the course?	
Collaboration	25
Understanding the design process	15
Design meeting practices	9
Learning method	8
Students' motivation	7
BIM	7
What should be developed?	
Guidance	12
Instructions	11

Of 35 feedbacks, in 25 was mentioned collaboration between students as a success of the course. One of the main aims of the course is to practice multidisciplinary collaboration skills needed between the stakeholders during the building design process. One student group describes the positive side of the course as follows:

*"Development of the collaboration and interaction skills, and increase of understanding the challenges of the different construction stakeholders' activities"*

In 15 feedback students underlined that their understanding about the design process was developed during the course. In following, there are two examples on how students describe their perceptions on course:

*"The course demonstrated well the progress of the design process"*

*"You can perceive the wholeness a completely different way in this kind of courses, where you work by yourself, even this widely"*

Also, the knowledge creation approach was fulfilled during the course. The following comments describe the nature of the inquiry based learning, students' motivation and their own responsibility of their learning during the course:

*"There should be more this kind of courses, because this course is similar to the engineers' tasks in working life. At first, you have to define the problem and then solve it yourself."*

*"It's good that the students have the main responsibility of the course progress. It gives a better picture of what kind of each role would be in working life"*

*"The whole group had good motivation and the work was done, "like in real project"."*

Twelve feedbacks indicate that students did not get enough guidance during the course. Many students think that especially task related guidance was insufficient and they did not get feedback from their outputs. The guidance varies a little depending of the year and student's role during the course. The following comment from the BIM-coordinator describes the students' perception well:

*"Some kind of feedback during the course would have been nice. There was not information on the success of our own task"*

Another negative aspect, which arisen from the feedback, was instructions of the course. In 11 feedbacks were mentioned that the students would have needed better instructions at the beginning of the course or more explicit pre-defined task for each role. They found that they did not know what kind of task fall into their role. Some students also found that the objectives were unclear. The following comment describes the students' perceptions:

*"At the beginning of the course there was not a clear understanding about the design order. Better instruction at the beginning would be given a better starting point for the course"*

In general, feedback by the students has been mainly positive. In the last learning event of the course, students have been present their perceptions of the course to the teachers and other students. In these events, many students have said that learning has been more meaningful and deeper than in traditional courses.

## **5. Discussion**

The obtained feedback is showing evidence that students have perceived that collaborative project-based learning has deepened their knowledge on the progress of the construction design process and their collaboration skills has improved. The course has been found motivating and the student-centric nature of it caused by students' possibility to affect on the content of the course and their responsibility of their own learning. Students' motivation is important in high quality

learning. Motivated students use more time on studying than other students, which affects positively on learning outcomes (Lonka & Ketonen 2012). Teachers' perceptions have been similar to students' perceptions. During the years, teachers have found that course simulate the appropriate way the real-life design process. Teachers have also noticed the high quality learning and the development of the students' knowledge and competence during the course. The course has shown that with new learning methods can make learning more context-oriented and enhance students' motivation, which are related positively on students' learning (see Lonka & Kettunen 2012).

The students' perceptions that their understanding about the design process have increased during the course, was one of the main results of the study. This is interesting. The master students, who have already been studying the design process in previous courses, have not achieved deep learning in courses, where have been used traditional teaching methods, lectures and assignment. Students have perceived that the course, where students plan the progress of the project by themselves, seems to lead higher quality learning than other courses.

Also, the results indicate that some students require well-defined instructions and more supervising during the course. The open and unlimited learning tasks confused some students, which is quite common in inquiry-based learning (see e.g. Salmisto & Nokelainen 2015). Therefore, the results showing evidence that students' metacognitive skills were inadequate for open-ended learning tasks. In previous courses, students are used to solving limited tasks predefined by their teachers. On the other hand, the most important aspect in inquiry-based learning is that students themselves define meaningful problems and formulate substantial research questions. Meyers & Nulty (2009) argue that learning in authentic learning environments, which contain for example ill-defined tasks, promotes students' ability to formulate relevant task-related questions later in their working lives. According to Korhonen-Yrjänheikki (2011) the ability to formulate the research questions is a significant skill for future engineers. Engineers will run up against unstructured and complicated tasks in working life. They should be able to define the main problems and to find the solution to them.

## **6. Conclusions**

The "Simulation of building design process" -course has been conducted in Tampere University of Technology in Finland since 2006. During the years, the teachers of the course had been noticed that course design has facilitated students learning in an appropriate way. In this paper, it was presented a practical model how to implement the multidisciplinary collaborative course design within the course. The paper has given a concrete example of the course design. The university teaching developers and teachers could use the presented model to develop teaching in construction higher education. The presented model based on project based learning and progressive inquiry learning methods and dialogical approach to learning. These methods develop learning of the contents, but also students' competency needs of the knowledge society, like presenting substantial research questions and metacognitive skills.

The empirical sample of the paper consisted of student feedback on how they have perceived the course design. Most students found that course has improved their multidisciplinary collaboration skills and the understanding about the building design process. These skills are needed in the complex construction projects of the real working life. Some students have found that they have not got enough feedback from their tasks during the course. Some students should have needed better instructions at the beginning of the course. The open-ended and unlimited tasks were confused some students. On the other hand, engineering students should be able to define problems and find solutions by themselves.

The results of this case study suggest the potential of using collaborative learning in the context of the construction process. Multidisciplinary and collaborative projects can be effectively used in higher civil engineering education to promote students' learning and develop collaboration skills which are required today's more and more complex construction projects and working life. In engineering studies, the learning methods of this kind should be used already earlier than only in master studies. If students learn needed skills of collaborative learning already in bachelor courses, they can take advantage of the new learning methods more effectively in later studies. That will affect positively learning of the contents.

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# An analysis of student performance measures in newly constructed schools

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## Abstract

Public school construction represents a significant portion of all construction spending in the United States, ranging from 7 to 9.5 percent annually from 2008 to 2013. This paper examines whether new construction, building age, and building condition affect applications, enrollment, attendance, and student achievement measures in a large urban school district in Texas, USA. Demographic data, including minority ethnicity (Hispanic and African American) and economically disadvantaged percentages were used to control for factors influencing the dependent variables. Twenty-eight magnet elementary schools (kindergarten to 5<sup>th</sup> grade) in one large school district were chosen for analysis. The experimental group ( $n = 14$ ) included all magnet elementary schools rebuilt under the 1998, 2002, and 2007 school bond ordinances. The control group ( $n = 14$ ) included randomly selected elementary schools from the 32 remaining magnet elementary schools that were not rebuilt during the same period of time in the same school district. Multiple and linear regressions were conducted, and the findings indicate no observable predictive effect on student enrollment or student attendance as evidenced by building composite score and building age. However, student achievement is positively related to having a new facility, as evidenced by the ability to predict state percentile rankings based upon building composite scores. This study demonstrates the impact facility managers and other school stakeholders may have by showing a positive connection between a school's physical condition and student performance and achievement.

**Keywords:** Schools, Building Performance, Student Performance, Construction, Magnet

## 1. Introduction

Public school construction (Pre-K to 12<sup>th</sup> grade) represents a significant portion of all construction spending, ranging from 7 to 9.5 percent annually from 2008-2013 (US Census 2014). A 1999 report for the National Center for Education Statistics (NCES) stated that public school age averages 42 years old.

Of those public schools, 28 percent were built before 1950, and 45 percent were built between 1950 and 1969 (NCES 1999). From this, one can infer that the condition of public schools is of great concern due to aging infrastructure, decades of deferred maintenance, environmental factors, lack of adequate technology, and failure to meet current accessibility standards. School funding is a complex issue, with few dollars from annual district budgets earmarked for maintenance, let alone capital construction. The overwhelming majority of public school construction is funded through local school bond funds requiring an election. For a bond referendum to pass, the public must understand the need for funds, know how funds will be allocated, believe students and the whole community will benefit from construction, and trust that projects will be completed on time and within budget.

Public education in the United States is more high-stakes than ever before for states, school districts, and schools, due to the standards-based movement, testing pressures and persistent achievement gaps. Penalties for not meeting Adequate Yearly Progress (AYP) are significant. The stakes and penalties are just as high for the people involved, including principals, teachers, and above all, students, who fail to meet minimum standards. The cost increase of constructing new schools to replace old ones is also steep. The average cost of a new elementary school in the Houston Independent School District (ISD), Texas, for example, is about \$16 million including furniture and technology. A new high school under the \$1.2 billion Houston ISD 2012 bond program will cost exponentially more, with several individual projects costing more than \$100 million, depending on size. Public confidence in school districts hinges upon a number of factors, including student achievement and perceived benefits of investing in bond programs.

The basic aim of this paper is to examine whether construction, building age and building condition affect enrollment, attendance and student achievement. In doing so, the paper may provide school districts with additional information to strengthen public confidence which, in turn, may lead voters to support school bond elections. Creating an observable connection between school construction and student outcomes may strengthen the likelihood of increased spending in this sector of the construction market, thereby benefiting the construction industry as a whole. This paper uses statistical data obtained from a large urban school district in Texas, USA, for the purpose of conducting data analysis and drawing conclusions

## **2. Literature Review**

Creating an observable connection between school construction and student outcomes is necessary for increasing public confidence in the bond election process. In turn, the construction industry benefits by way of increased funding. Efforts to reduce the achievement gap between students belonging to different socio-economic classes began with the passing of Title I of the Elementary and Secondary Education Act (1965). These were mainly centralized efforts, with federal funding provided to schools with a high level of poverty, to be used for school-wide improvement and reform strategies. Later, in 1998, with the Comprehensive School Reform Program (under title 1 part F of Title I of the Elementary and Secondary Education Act,

1965), grant opportunities were awarded to public schools willing to implement research-based school reform strategies targeted toward reducing the achievement gap. A number of studies have linked student performance with building conditions: McGuffey (1982) and Weinstein (1979) examined a total of 238 studies and 21 paper presentations to understand the effects of a number of factors like building age, building utilization, school size, etc., on student performance. In a review of more recent research, Earthman and LeMasters (1996) concluded that research has-

“...demonstrated a relationship between student performance, both achievement and behavior, and the condition of the built environment. The relationship has varied from very weak in some early studies to the most recent study which demonstrates a considerable degree of relationship. Nevertheless the preponderance of the research cited shows a very close relationship between the built environment and how well students and teachers perform in that environment.” (p.11).

Schneider (2002) also reviewed the body of research around school quality and student achievement and concluded that school facilities affect learning: spatial configurations, noise, heat, cold, light, and air quality – all bear on students’ and teachers’ ability to perform. He also found that building age alone cannot be used as a predictor of performance, thus implying that a different measure of building quality could be measured and achieved through adequate funding and competent design, construction and maintenance (Schneider, 2002). Lyons (2001) drew similar conclusions after a review of research around facility conditions. He pointed out that changes in teaching and learning, technology, and increasing accountability and standards require changes in school facilities to be flexible enough to allow for collaboration.

In another canonical analysis, Crampton (2009) used longitudinal, state-by-state data about school spending and student achievement from the Institute for Education Sciences and the United States Census Bureau to determine the impact of human, social, and physical capital on student achievement. “Human” and “social” capital focused on the quality of teachers and professional development, examining dollars spent. “Physical” capital referred to school infrastructure, condition and adequacy with spending determined by dollars spent for maintenance and capital outlay, including construction, renovation, and debt for capital outlay. The National Assessment of Educational Progress (NAEP) scores for 5<sup>th</sup> and 8<sup>th</sup> grade reading and math were used as measures of student achievement. Over the years examined (2003, 2005, and 2007), and controlling for poverty, dollars spent on human, social and physical capital accounted for between 55.8 and 77.2 percent of the variation in scores. Human capital investments showed the largest effect over time at .890 in 2003 and declining to .648 in 2007. Social capital produced a coefficient of .158 in 2003, dipped in 2005, and rose to .299 in 2007. Physical capital was more varied in its effects, accounting for .236 in 2003, .049 in 2005, and rose back to 2003 levels in 2007. While human and social capital effects were higher overall, the researcher concluded, “...the impact of investment in physical capital...was also a significant contributor...spending on school infrastructure does matter when it comes to student achievement” (Crampton, 2009, p.318).

Based on the belief that environment affects outcome, Berner (1993) studied the impact of parental

involvement on building condition by creating a regression model using Parent Teacher Association (PTA) membership, PTA budget, school condition (1=excellent, 2=fair, 3=poor), type of building, school age, percent white, mean household income, and student enrollment. In the second part of the study, regression was used to analyze if the overall building condition impacted student achievement as shown by the schools' average California Test of Basic Skills (CTBS) scores. Berner's (1993) findings supported the hypothesis that student scores improved as building conditions improved. This hypothesis was also supported by studies conducted by Uline and Tschannen-Moran (2008). Using qualitative methods, they surveyed teachers at 80 Virginia middle schools to look at links between school facility and student achievement using school climate as the mediating variable. Their study observed links between building condition and an overall atmosphere that encouraged teaching and learning; they concluded that building conditions indeed did affect student achievement. One study, the Holistic Evidence and Design (HEAD) project (Barrett et al., 2015), shows promising progress in understanding the ways in which the built environment may impact student learning. The seven key design parameters that best predict students' progress were found to be light, temperature, air quality, ownership, flexibility, complexity and color. The HEAD study focused on specific design parameters and their impact on student learning, while the study presented in this paper takes a different perspective, emphasizing building age and condition as predictors for student enrollment and achievement.

### 3. Research Methods

The population for this study consisted of all elementary schools in the Houston ISD. A sample of 28 magnet elementary schools was gathered. The experimental group was not randomly sampled since all 14 replacement (rebuilt) magnet elementary schools were included; however, the 14 schools in the control group were randomly selected from a pool of more than 30 other magnet elementary schools not rebuilt. All 28 magnet elementary schools in the sample were identified from the three bond elections that the school district passed in 1998, 2002, and 2007.

The study examined whether major renovation, building age, and building condition had an impact on magnet applications, enrollment, attendance, and student achievement measures. All variables and the sources from which they were obtained are listed in Table 1.

*Table 1: Study variables and their sources*

<i>Data</i>	<i>Variable</i>	<i>Source</i>	<i>Reference</i>
<i>School Enrollment</i>	<i>Dependent</i>	<i>School Digger website</i>	<i>schooldigger.com</i>
<i>Magnet Application</i>	<i>Dependent</i>	<i>District Data via HSS website</i>	<i>houstonschoolsurvey.com</i>
<i>School Attendance Rate</i>	<i>Dependent</i>	<i>School Digger website</i>	<i>schooldigger.com</i>
<i>Student Achievement</i>	<i>Dependent</i>	<i>School Digger</i>	<i>schooldigger.com</i>

		<i>website</i>	
<i>Free and Reduced Lunch Percentage</i>	<i>Control</i>	<i>School Digger website</i>	<i>schooldigger.com</i>
<i>Minority Percentage (Hispanic &amp; African-American)</i>	<i>Control</i>	<i>School Digger website</i>	<i>schooldigger.com</i>
<i>Age of Original Building</i>	<i>Independent</i>	<i>District Study</i>	<i>Houston Independent School District and Parsons (2012)</i>
<i>Completion Date of Building</i>	<i>Independent</i>	<i>District Study</i>	<i>Houston Independent School District and Parsons (2012)</i>
<i>School Composite Facility Score</i>	<i>Independent</i>	<i>District Study</i>	<i>Houston Independent School District and Parsons (2012)</i>
<i>Statewide percentile ranking in “Reading” and “Math”</i>	<i>Independent</i>	<i>School Digger website</i>	<i>schooldigger.com</i>

For the set of 28 magnet elementary schools, which included experimental and control groups, multiple regression methods were used to examine the relationships among the independent variables of building age and building composite in 2011-2012, with dependent variables of magnet applications, student enrollment, student attendance and student achievement. Minority percentages of combined African-American and Hispanic student populations, and percentages of free and reduced lunches were included in the full regression model as control variables.

## 4. Results

Descriptive statistics for the experimental and control schools, as analyzed from the sources mentioned above, are shown in Table 2. Even though the two groups studied are significantly different from each other in terms of building age and building condition scores, they do not significantly differ in enrollment numbers for school year 2011-2012 and the number of magnet applications for school year 2013-2014. Mean 2011-2012 enrollment numbers for the experimental schools and for the control schools was 739.2 and 695.1, respectively, and mean 2013-2014 magnet application numbers for the experimental schools and for the control schools was 237.4 and 239.6, respectively. The data presented in Table 2 also emphasizes the high percentages of free and reduced lunch students and the high percentage of minorities (as measured by percentage of African-American and Hispanic students) within the two groups examined in this study.

Table 2: Experimental and control schools descriptive statistics

	Experimental schools (n=14)			Control schools (n=14)		
Variable	Min.	Max.	Mean (S.D)	Min.	Max.	Mean (S.D)
Building age in 2011-2012	0	8	4.07 (2.81)	20	92	61.29 (23.53)
Building composite in 2011-2012	85	100	93.04 (6.56)	39	87	72.12 (11.80)
Enrollment in 2011-2012	607	918	739.2 (77.2)	518	916	695.1 (131.0)
Magnet applications for 2013-2014	10	619	237.4 (207.3)	10	677	239.6 (249.2)
Percent free & reduced lunch for 2011-2012	14.5	53.6	40.28 (11.24)	5.6	58.3	30.14 (17.66)
Percent African-American and Hispanics for 2011-2012	41.8	99.1	86.89 (17.85)	20.8	99.5	60.17 (29.19)

First, we examined whether there was an observable effect on magnet applications by looking at building composite score and building age in the experimental and control schools. Tables 3 and 4 show the model summary for experimental and control schools: magnet applications and the ANOVA results.

Table 3: Model summary for experimental and control schools: magnet applications

	Experimental schools (n=14)			Control schools (n=14)		
Model	R	R <sup>2</sup>	Standard error (SE) of the Estimate	R	R <sup>2</sup>	Standard error (SE) of the Estimate
1	.168	.028	222.1	.409	.168	247.2

Table 4: ANOVA results for experimental and control schools: magnet applications

Experimental schools (n=14)					
Model	Sum of Squares	df	Mean Square	F	Sig.
Regression	15,708.2	2	7,854.1	.159	.855
Residual	54,278.2	11	49,343.7		
Total	558,489.4	13			
Control schools (n=14)					

<i>Model</i>	<i>Sum of Squares</i>	<i>df</i>	<i>Mean Square</i>	<i>F</i>	<i>Sig.</i>
<i>Regression</i>	135,263.7	2	67,631.8	1.107	.365
<i>Residual</i>	671,945.8	11	61,086.0		
<i>Total</i>	80,209.4	13			

The coefficient of determination was not significant for either the experimental schools ( $R^2=0.028$ ,  $F(2,11)=0.159$ ,  $p = 0.855$ ) or the control schools ( $R^2=0.168$ ,  $F(2,11)=1.107$ ,  $p = 0.365$ ). Therefore, we infer that there was no observable effect on magnet applications as evidenced by building composite score and building age in the experimental and control schools.

Next, we looked at whether enrollment can be predicted using building age and building composite score. Tables 5 and 6 show the model summary for experimental and control schools: enrollment and the ANOVA results.

*Table 5: Model summary for experimental and control schools: enrollment*

	<i>Experimental schools (n=14)</i>			<i>Control schools (n=14)</i>		
<i>Model</i>	<i>R</i>	<i>R<sup>2</sup></i>	<i>Standard error of the Estimate</i>	<i>R</i>	<i>R<sup>2</sup></i>	<i>Standard error of the Estimate</i>
<i>1</i>	.390	.152	77.225	.371	.138	132.233

*Table 6: ANOVA results for experimental and control schools: enrollment*

<i>Experimental schools (n=14)</i>					
<i>Model</i>	<i>Sum of Squares</i>	<i>Df</i>	<i>Mean Square</i>	<i>F</i>	<i>Sig.</i>
<i>Regression</i>	11,774.1	2	5,887.1	.987	.403
<i>Residual</i>	65,602.3	11	5,963.8		
<i>Total</i>	77,376.4	13			
<i>Control schools (n=14)</i>					
<i>Model</i>	<i>Sum of Squares</i>	<i>df</i>	<i>Mean Square</i>	<i>F</i>	<i>Sig.</i>
<i>Regression</i>	30,780.9	2	15,390.5	.880	.442
<i>Residual</i>	192,342.7	11	17,485.7		
<i>Total</i>	223,123.2	13			

The coefficient of determination was not significant for either the experimental schools ( $R^2=0.152$ ,  $F(2,11)=0.987$ ,  $p = 0.403$ ) or the control schools ( $R^2=0.138$ ,  $F(2,11)=0.880$ ,  $p = 0.442$ ). Therefore, there was no observable effect on enrollment as evidenced by building composite score and building age in the experimental and control schools.



In the next step, we analyzed whether student attendance can be predicted using building age and composite building score. Tables 7 and 8 show the model summary for experimental and control schools: attendance and the ANOVA results.

*Table 7: Model summary for experimental and control schools: attendance*

	<i>Experimental schools (n=14)</i>			<i>Control schools (n=14)</i>		
<i>Model</i>	<i>R</i>	<i>R<sup>2</sup></i>	<i>Standard error of the estimate</i>	<i>R</i>	<i>R<sup>2</sup></i>	<i>Standard error of the estimate</i>
<i>1</i>	<i>.313</i>	<i>.098</i>	<i>.386</i>	<i>.314</i>	<i>.098</i>	<i>.510</i>

*Table 8: ANOVA results for experimental and control schools: attendance*

<i>Experimental schools (n=14)</i>					
<i>Model</i>	<i>Sum of Squares</i>	<i>Df</i>	<i>Mean Square</i>	<i>F</i>	<i>Sig.</i>
<i>Regression</i>	<i>.177</i>	<i>2</i>	<i>.089</i>	<i>.596</i>	<i>.568</i>
<i>Residual</i>	<i>1.635</i>	<i>11</i>	<i>.149</i>		
<i>Total</i>	<i>1.812</i>	<i>13</i>			
<i>Control schools (n=14)</i>					
<i>Model</i>	<i>Sum of Squares</i>	<i>df</i>	<i>Mean Square</i>	<i>F</i>	<i>Sig.</i>
<i>Regression</i>	<i>.312</i>	<i>2</i>	<i>.156</i>	<i>.600</i>	<i>.566</i>
<i>Residual</i>	<i>2.857</i>	<i>11</i>	<i>.260</i>		
<i>Total</i>	<i>3.169</i>	<i>13</i>			

The coefficient of determination was not significant for either the experimental ( $R^2=0.098$ ,  $F(2,11)=0.596$ ,  $p = 0.568$ ) or control schools ( $R^2=0.098$ ,  $F(2,11)=0.600$ ,  $p = 0.566$ ). Therefore, we infer that there was no observable effect on attendance as evidenced by building composite score and building age in the experimental and control schools.

Last, we analyzed whether student achievement was positively impacted by a new facility as evidenced by state percentile ranking based upon building composite scores. Ranking was determined by adding total “Reading” and total “Math” scores across all grades tested on the state standardized assessment ranking within Texas public schools (SchoolDigger.com). In the experimental model, 47.1% of the variance in state percentile ranking was accounted for by building composite scores ( $F(1,12) = 10.686$ ,  $p=0.007$ ). The unstandardized regression equation was found to be  $Y = 14173.313 + -129.010 (X_1)$ . This was significant at  $t=-3.269$ ,  $p = 0.007$ .

In the control model, 53.4% of the variance in state percentile ranking was accounted for by building composite scores ( $F(1,12) = 13.772$ ,  $p=0.003$ ). The unstandardized regression equation was  $Y = 5570.307 + -62.448 (X_1)$ . This was significant at  $t=-3.711$ ,  $p = 0.003$ . Table 9 shows the model summary for

experimental and control schools: statewide rank; Table 10 shows the ANOVA results. Table 11 shows the regression models for experimental and control schools.

*Table 9: Model summary for experimental and control schools: statewide percentile rank*

	<i>Experimental schools (n=14)</i>			<i>Control schools (n=14)</i>		
<i>Model</i>	<i>R</i>	<i>R<sup>2</sup></i>	<i>Standard error of the estimate</i>	<i>R</i>	<i>R<sup>2</sup></i>	<i>Standard error of the estimate</i>
<i>1</i>	.686	.471	933.7	.731	.534	715.7

*Table 10: ANOVA results for experimental and control schools: statewide percentile rank*

<i>Experimental schools (n=14)</i>					
<i>Model</i>	<i>Sum of Squares</i>	<i>df</i>	<i>Mean Square</i>	<i>F</i>	<i>Sig.</i>
<i>Regression</i>	9,317,339.7	1	931,7339.7	10.686	.007
<i>Residual</i>	10,462,991.2	12	871,915.9		
<i>Total</i>	19,780,330.9	13			
<i>Control schools (n=14)</i>					
<i>Model</i>	<i>Sum of Squares</i>	<i>Df</i>	<i>Mean Square</i>	<i>F</i>	<i>Sig.</i>
<i>Regression</i>	7,053,564.4	1	7,053,564.4	13.772	.003
<i>Residual</i>	6,146,099.3	12	512,174.9		
<i>Total</i>	13,199,663.7	13			

*Table 11: Experimental and control school regression models: statewide percentile rank*

<i>Experimental schools (n=14)</i>				
<i>Model</i>	<i>B</i>	<i>Standard Error</i>	<i>T</i>	<i>Sig</i>
<i>Constant</i>	14,173.3	3,680.4	3.8	.002
<i>Building Composite</i>	-129.0	39.5	-3.3	.007
<i>Control schools (n=14)</i>				
<i>Model</i>	<i>B</i>	<i>Standard Error</i>	<i>T</i>	<i>Sig</i>
<i>Constant</i>	5,570.3	1,228.5	4.5	.001
<i>Building Composite</i>	-62.4	16.8	-30,711	.003

## 5. Conclusions and Future Research

School districts in the United States are under intense pressure to perform, with significant penalties imposed on them in cases where they do not meet minimum achievement standards. Added to this pressure

is the fast-increasing cost of school construction and renovations. The achievement gap continues to be an issue for at-risk, low-income, and minority students. Research shows that a number of societal and school factors contribute to this gap and a multi-pronged approach appears to be the only way to narrow it. As a result, student achievement and perceived benefits of investing in bond programs lay at the center of public confidence in school districts.

The current study examined the effects of physical building quality on magnet applications, enrollment, attendance, and student achievement. Among magnet elementary schools in the Houston ISD, this study found no significant correlation in magnet applications, enrollment, or attendance for experimental (replacement) schools as compared to a control sample of other magnet elementary schools for the year of interest. However, for the most critical question of student achievement, building a replacement school did make a difference, explaining 47.1% of the variance in scores. In this model, other previously significant factors, such as minority population and free and reduced lunch percentages, no longer held the same level of significance or else dropped from significance altogether. It is encouraging to find that the quality of the school environment can, at least in part, have an impact on student achievement and the achievement gap by creating high-quality learning environments. These results could be used to strengthen public confidence in current and future bond programs within and outside of the Houston ISD, if shared with school board members, district personnel, and public stakeholders. Successful bond programs that produce benefits beyond just construction are definitely good for the construction industry as a whole.

This study could readily be replicated and even expanded within the Houston ISD. Research could look at additional testing years or consider a longitudinal approach to see how schools and students fare in the years post-construction. While this study only looked at replacement elementary schools, a broader study could look at all schools based upon building composite scores from 2012, since the effects could also hold for well-maintained or renovated schools, not simply new ones. It would be interesting to see if the same results would be produced when Houston ISD replacement high schools are completed in the coming years. Lastly, with such robust, varied, and longstanding standardized testing within Houston ISD, researchers may also benefit from using student-specific test scores instead of overall school rankings.

Combining qualitative research methods with quantitative ones could further explain why replacement schools make a difference in student achievement. Post-occupancy surveys of principals, teachers and students could be particularly helpful, especially at the high school level, since students have a greater ability to respond.

The construction and facility management industry, along with education researchers, could and should be an active part of research in this area. Showing how new buildings positively affect students and the greater public benefits the industry financially and could also boost the morale of construction professionals who rarely get to see the difference spaces make once the punch list is complete. Even more importantly, improving student achievement affects the future lives of students and society as a whole by increasing the likelihood of high school graduation, college attendance, and earnings potential. Bettering lives, decreasing

the cycle of poverty, and enhancing the national economic picture through improving school facilities is truly priceless.

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# Extending Professional Fields: Architectural Research and Regional Development

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## Abstract

In this article, architectural research work is studied as an effective operations model in regional innovation networks of building clusters. The study focuses on the projects of an academic research team working at the University Centre of Seinäjoki, as well as on the innovation environment of the surrounding South Ostrobothnian region in Western Finland. There is no actual university in the region, but the University Centre hosts some twenty professors and their research teams from six Finnish universities. The head of the subject team is also the author of this article. Because of this, the method applied in the article is a reflective action research approach.

The actions and impacts of the research work will be analysed through three case projects. The first case is the development of the large railway station area that will form a new 20-hectare multifunctional part of the city centre of Seinäjoki. The project has strong linkages to the economic policies of the city. The second case is related to the boom in new timber construction, which has been going on in Central Europe and Scandinavia for some time, but not so strongly in the subject region of this study. The aim of the project was to train small and medium-sized building cluster firms to take advantage of the emerging business potential in timber construction. The third case is closely related to the real speciality of the region. The city of Seinäjoki is home to one of the most complete building groups of architect Alvar Aalto, the famous civic centre that consists of the town hall, library, theatre, office building, church and the parish centre. At the moment there is a very demanding renovation project going on, which was also the main subject of the recent research and development project.

The descriptions of the projects are meant to illustrate the operational field of the research team, but the main focus of the article is to analyse the innovation environment that the researchers join as players among others, thus deviating from the more conventional role of architectural professionals.

**Keywords:** Architectural research, urban planning, urban development, regional development, innovation environment

# 1. Introduction

In this article, the possibilities of one research team to contribute successfully to regional development will be analysed. The team comprises the Urban Laboratory<sup>1</sup> researchers from Tampere University of Technology (TUT), School of Architecture. The geographical operations area of the team is the South Ostrobothnia region in western Finland, with a focus on the urban region of its capital city, Seinäjoki. The leader of the team is a professor of architectural and urban research. Individual team members might change during the course of the projects, but the professor will remain constant. Because of this, the professor serves as sort of an “object lens”, through which actions will be observed in this study. Moreover, the leading professor is also the author of this article, so the applied research method is most akin to reflective action research.

At present, the first five-year period of the professorship has passed, and the second is well under way. Some self-evaluation is necessary for being able to improve future actions. Publishing the results enables feedback from a variety of experts. It is always problematic to reflect on one’s own actions, as personal limitations and competences are difficult to assess objectively. Despite this, the work has to be done, and hopefully the results will benefit similar developers elsewhere. It is also hoped that the study presents an interesting, albeit not so typical, view of an architect’s and a researcher’s field of operations.

Seventy-five percent of the funding for the professorship will be collected from private companies and public organisations of the subject region. This will not succeed unless its contribution is considered of value. The benchmark for success is the benefit that the research team produces for the regional building cluster, whether directly or indirectly through urban development. The university has its own credit systems that consist of peer-reviewed articles, doctoral theses and academic research funding.

The problem is that applied research and regional activities are not taken into account in the scientific credit systems of universities. Consequently, it takes a lot of work and creativity to formulate the projects and funding applications so that they can eventually result in scientific publications. This raises critical questions of the societal role, the so called “third task” of universities, stipulated in the Universities Act. If the research is considered worthy of regional funding, why can’t it be indicated and included in the credit systems?

In this study, the regional operations environment is limited to building cluster and municipal urban planning. Because the vantage point of the study is in the sphere of economic development, it is fair to use the term “innovation environment” (Mustikkamäki & Sotarauta 2008). There is a university of applied sciences in the region that gives education in civil engineering, but there is no academic education for engineers or architects. A characteristic feature of the region is the strong entrepreneurial spirit and a great number of small and middle-sized firms, but there is relatively little technological research and development typical of big companies. The planning offices of the region’s municipalities are overloaded with work, allowing no resources for development there either. Considering all this, one important task of the research team has been to import the latest knowledge and to extend specialist networks to the region.

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<sup>1</sup> <http://www.tut.fi/en/alvar-aalto-chair>

## 2. Operating environment

The professorship and the team started their work in 2009. The early stages were truly pioneering work, since the whole platform for successful research had to be constructed piece by piece: recognising partners and networks, identifying their needs, and formulating research topics so that they were relevant not only from the regional perspective, but also sufficiently appealing to national research funders. The University Consortium of Seinäjoki (UCS)<sup>2</sup> requires that the research should in some way support regional economic and urban development.

The original action plan of the professorship was based on the renovation problems of modernist architecture. Gradually this theme gathered more salience, and it became the conceptual “umbrella” over the diverse project portfolio, but first the theme had to be translated into wider terms. “Adaptability and resilience of the built environment” is the umbrella in this case. So far, three research lines have emerged under the umbrella: 1) new planning and design methods, 2) built environment in transition, and 3) special issues of modernist built heritage. These lines consist of several ongoing projects, as well as closed ones, some pending or under preparation.

Conceptual conjoining is necessary for fulfilling the needs of both of the background communities of the professorship: UCS requires visibility and effects in the regional context, whereas TUT has exact systems of academic credits and performance criteria concerning all professorships. Quite often regional research and development projects can be characterised as applied science due to available partners and funding instruments. It is easier to refine them into academic publications and theses, if there is a connecting framework, functioning as a conceptual “umbrella”, constructed gradually on the basis of the project findings.

The projects include wide collaboration with the partners in South Ostrobothnia and in the city of Seinäjoki, as well as with the education and research institutes of the region. A remarkable part of the academic co-operation originates from the physical context of UCS, since it provides premises for six universities and 20 professors with their research teams<sup>3</sup>. Some projects are actually kicked off in the lobby when two researchers from different disciplines meet by chance.

The city of Seinäjoki and its development office collaborate frequently with UCS research units. This is how the city officers utilise research in their economic, social or urban development. However, the locality itself is very seldom the actual subject of research, but more usually a laboratory for diverse experiments. In this respect Seinäjoki has some advantages due its modest size with 60 000 inhabitants, dynamic and development-friendly atmosphere, and very approachable key actors and institutes. But it is also a growth city with growth problems, which makes it interestingly comparable to larger cities. In addition, its built environment matches perfectly to the team’s research themes: the city centre has been built almost entirely after WWII, and furthermore, it features one of the iconic works of modernist architecture, Alvar Aalto’s civic centre.

In practice, research operations will be conducted on two levels. The first level consists of research and development projects. The professor writes research plans and makes preparations for launching

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<sup>2</sup> <http://www.ucs.fi>

<sup>3</sup> <http://www.epky.fi/epanet>

projects. He also hires researchers and leads the projects. The second level is based on the professor's own research benefiting from the project findings.

Practical operations include applications for funding of the research projects, engaging researchers and partners, launching and leading projects. One of the main objectives in the near term is to integrate research into international networks. This requires partnerships in EU-funded projects, joining international conferences, publishing in scientific journals, and organising international workshops. Obviously, the academic collaboration continues on a national level, but applying for EU-funds for research is unavoidable due to reductions in the allocations of national research funds.

The results of the team can be divided into three main groups: 1) scientific results consisting of new theories and applications, and publications that report the results, 2) increasing knowledge and skills of the students and partners, and consequent changes in thinking models and practices, and finally 3) such changes in built environment that improve its adaptability, transformability and resilience.

### **3. Innovation environment**

In South Ostrobothnia the main issue is the region's economic competitiveness. Municipalities and firms should have competencies that exploit new operations models, technology and markets. In practice, the firms and organisations should be able to complement their own internal resources and competences by obtaining complementary resources from external sources. In this sense the *innovation environment* is the specific part of the operation environment of firms and organisations that provides complementary competences and resources the firms and organisations need in their innovative endeavours. However, the innovation environment is not the same for all enterprises and organisations, since their needs are different. (Cooke, 2004; Kautonen, 2008) Yet, from the standpoints of local and regional development, the regional innovation environment could be considered a common innovation environment for some specific field of industry or administration. Important elements of these environments include, among other things, education, research and development, technical infrastructure, management consultancy and financial support (Camagni, 1991; Virkkala, 2008.)

The term "regional" does not imply that all the resources and competencies will come from the local region. Local and global entities should form a fruitful collaboration to create new know-how. Local arenas are needed for close interaction, and global connections are needed for distant communication. No region is self-sufficient enough to be able to provide all the necessary competencies. In addition, the geographical scales of firms and organisations vary (see Kolehmainen, 2004; Lechner & Dowling, 2003), as some companies in South Ostrobothnia have established international trade relationships, and the city of Seinäjoki joins diverse national networks.

It is important to note that firms and organisations do not innovate alone. Innovations are developed in networks that consist of diverse actors which include, for example, clients, subcontractors, competitors, financiers, administrators, trade associations, development organisations and research institutes. The innovation network includes all those players that contribute to innovation processes (Cooke & al., 2000; Lundvall, 2001; Virkkala, 2008). If the processes take place in the normal practices of firms and organisations, they are sometimes referred to as open innovation, as opposed to science-based processes. Some studies point out that new innovations are mostly developed in practice-based settings (Harmaakorpi & al., 2011; Chesbrough, 2003a, 2003b).



Innovation networks consist of social relations. The qualities of those relations have an effect on the performance of the networks as facilitators of production, economy and administration. Network relations can be divided between those with strong ties and those with weak ties. Usually the strong ties are based on trust between parties, common goals and easy communication due to common language and similar basic access to information. However, strong ties do not necessarily encourage firms and organisations to combine different ways of thinking and acting that finally might result in new innovations. Studies have pointed out that open innovation utilises the weak ties of networks especially. Weak ties force firms and organisations to seek solutions from new kinds of reference groups, which might result in fruitful mixes of information and, perhaps, ultimately in new innovations. (Burt, 1992; Granovetter, 1973.)

It is not possible to anticipate or control the processes that take place in innovation environments, but the innovation environment itself could be developed deliberately (Sotarauta & Srinivas, 2006). For example, regional arenas for interaction and collaboration between different competences could be organised. These kinds of settings have been termed development platforms by some researchers (see Harmaakorpi & al., 2011). Competence-based platforms are able to combine diverse knowledge and create novel variations of competences, as experts from industry, universities and municipalities gather around some common theme or technology.

Development platforms are fundamentally future-oriented arrangements (Harmaakorpi & al., 2011). Technological development by its own right is capable of creating new platforms, but usually they are based on the evolution of existing platforms. In South Ostrobothnia the development paths of, for example, timber construction can be easily traced back in the region's history. Traditional rustic houses, high-grade carpentry skills and a strong entrepreneurial culture are well-known characteristics of the region. Yet it requires a visionary mind-set to recognise the elements of evolving platforms that could merge existing potentials and global flows into a local success story. Also, innovation policies should be targeted to the specific features of regional innovation environments.

## **4. Action research**

One very suitable method for this kind of study is, arguably, action research. Although there isn't a widely-recognised, unambiguous definition for action research, the basic principles of the method can be recognised. The main feature of the method is the researcher's ambition to have an effect on the research subject, while being simultaneously a part of the subject. The objective behind the action is to change the practices and habits of the subject community by inspiring the actors to use practical reasoning to reflect on their actions. Thus the researcher is only a visitor whose intervention will set people free to act in their own best interests. At the same time the researcher is able to collect valuable information. (Reason & Bradbury 2001.)

The other essential feature of action research concerns the target group, which is always a particular community. It is also important that the community can be defined both geographically and temporally. However, the interaction between the researcher and the community does not need to be so strictly defined thematically; it should be relatively permanent and long standing. The researcher does not work alone, but together with the members of the community. This kind of study design enables both scientific and practical approaches. (Reason & Bradbury 2001) In this sense the method applies well to

the present study, where the actions are analysed principally within the overlap of academic and professional spheres.

In this case, there is one deviation from more “orthodox” action research. The study design described above has not been explicitly introduced to the target community. But, on the other hand, the whole idea of founding a regional university centre has been a deliberate method for the local development community to reflect its own actions. For example, one of the research units of the centre (the research team “Sente” from University of Tampere) aims to conduct research on innovation environments. There is also an explicit agreement with the Urban Laboratory team and the city of Seinäjoki to use the city as a living laboratory. And finally, these two units mentioned above have released joint publications on local economic and urban development in Seinäjoki (Hynynen & Kolehmainen 2011; 2016, forthcoming).

In the present study, the method has been applied as follows: The research team has actively participated in different innovation networks of construction and urban planning. The researchers have brought along their knowledge and made observations. This has mainly taken place in connection with research and development projects and different expert tasks. These activities have resulted in a multitude of research material, including project reports, scientific and professional articles, workshop and seminar presentations, as well as meeting memos and minutes. All this material has been available for the actors of the innovation networks.

## **5. Case studies**

### **5.1 Case 1: SmartStation**

In Seinäjoki, the railway station area was selected as the main urban development area, as the city’s administration made decisions to increase housing in the city centre. The key reason behind the decision was the fast growth of the population of the city. In past years growth has focused on the urban fringes, but now there are signs of growing demand for more urban alternatives to single-family houses. The city planners welcome this trend, for it enables improvement of service structure and urban image of the city centre, which has been considered too rural for the medium-sized<sup>4</sup> growth city that counts on research and the latest technology. (Seinäjoen kaupunki 2014)

Knowledge-driven development policy dominates the urban strategy of Seinäjoki (Seinäjoen kaupunki 2013), which is concretised particularly well in the goals set for the railway station area development. According to the objectives, the station area will form a third knowledge-based hot-spot alongside the Frami technology centre (UCS, SeAMK<sup>5</sup>) and Itikanmäki (Foodwest<sup>6</sup>, Rytmikorjaamo<sup>7</sup>).

Because the city’s land ownership is very low in the railway station area, it was considered important to engage the area’s other land owners and developers regarding the development objectives. There was a danger that if they start to develop their own premises in a piecemeal manner, the whole area would

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<sup>4</sup> Population ca. 60000.

<sup>5</sup> <http://www.seamk.fi>

<sup>6</sup> <http://www.foodwest.fi>

<sup>7</sup> <http://www.rytmikorjaamo.com>

be completed without a comprehensive and visionary master plan necessary for fulfilling the ambitious urban objectives.

Based on these ideas, the city of Seinäjoki launched the “SmartStation” project in collaboration with two universities (including Sente and Urban Laboratory), funded by Tekes<sup>8</sup>. The aim of the project was to organise an inclusive development process by arranging workshops for visionary goal-setting. From the very beginning the workshops were focused on urban qualities, and also on the economic profile of the area in relation to the other innovative hot-spots of Seinäjoki. The economic profile of the station area was further sharpened, as the city was included in the national “Innovative cities (INKA)” – development programme lead by the Ministry of Employment and the Economy. The South Ostrobothnia region is known in Finland as the “Food Province” due to its strong agricultural economy and advanced food technology. In the INKA-programme this kind of background justified the city’s acceptance into the category of bio-economy. Based on this, it was clear that the station area should be a global shop window for the Food Province.

In the workshop discussions, work and working life were dealt with the terms of change. The developing station area should meet this challenge with flexibility of spaces and infrastructure. Some concrete ideas were proposed, like mixing small scale production with office work and dwellings in hybrid buildings. Also, different “hubs” should have platforms, as well as apartment and office hotels for mobile workers. Functional mixes, spatial flexibility and excellent accessibility were important keywords in the final report of the project. These qualities are also very compatible with the emerging ideas of open innovation (Chesbrough, 2003a, 2003b; Hynynen & Kolehmainen 2016, forthcoming).

## **5.2 Case 2: Puu-Hubi (Wood-Hub)**

Wooden multi-story apartment buildings have been common in North America for a long time. Now, large-scale timber construction is proliferating in Europe as well. The main drivers for this development include, for instance, favourable environmental impacts of wooden building materials as well as general moisture problems associated with concrete buildings. In addition, the timber-based building industry has potential to support regional economic development (Männistö & al., 2012). This is true especially in countries like Finland, which have strong forest and wood industries, as well as long traditions in timber construction.

Based on these views, it could be assumed that there should be more development in this industry in South Ostrobothnia than there actually is. One explanation is the fierce competition in the construction business. Building firms do not easily change their familiar production platforms because of fear of economic risks. Also, producers of concrete materials are campaigning for their continued dominance. However, it is important to understand that the renewed interest in timber construction technology is only just getting started.

Our Puu-Hubi project highlighted interesting aspects of the roles of local and regional actors in the development of timber construction. In particular, cities and municipalities could promote win-win situations, as they are beneficiaries of regionally-entrenched value chains of the wood building industry. They also have authority in writing and applying laws and codes that have impacts on building costs. Municipal and regional developers could support wood building in many ways by including it in their

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<sup>8</sup> The Finnish Funding Agency for Innovation.

economic and development programmes. In our project the central network of regional players was easily distinguishable, although not all the actors recognised their own role as an effective node in the innovation network. The key players are in most cases building cluster firms like wood-producing enterprises, construction firms, property developers, architecture offices and civil engineers.

One of the main goals of the Puu-Hubi project was to figure out the information needs of the firms in new timber construction technologies. Many different theme areas were named, and our task was to organise training for the firms to provide competences to meet their needs. However, other resources beyond purely cognitive ones are needed as well. The firms should possess a so-called absorptive capacity (Cohen & Levinthal, 1990; Zahra & George, 2002). In other words, they need capabilities to evaluate, adopt and apply new information. But even if the firms have these capabilities, the birth of an innovation is anything but a systematic process, and lucky coincidences will still be needed.

In our subject region there have been many discussions on the possibilities of timber construction. The amount of information is no longer the decisive bottleneck in the breakthrough of the industry. Instead, strategic awareness should be awakened somehow (Sotarauta & al., 2007; Heifetz, 2003). University-led projects and workshops will not suffice as the only means, but real leadership is now needed. Somebody has to get down to business with clearly-defined goals, geared with the ability to lead networks. The first task is to create a storyline where diverse players are able to identify their roles and interests in a common endeavour (Simmons 2001). For example, firms and municipal development offices, as well as education and research institutes, should perceive their interdependence in an innovation network as a positive opportunity.

As one outcome of the Puu-Hubi project, the University Consortium of Seinäjoki is preparing a new professorship with the University of Vaasa. The branch of science will be the timber construction industry. If the consortium succeeds in funding the chair, the new specialist would have an interesting role in the innovation network. Will the new professor prove to be the node with strong links that is currently missing in the network? Either way, the chair will provide permanence and continuity for the innovation environment, but its holder will also be an important storyteller.

### **5.3 Case 3: MARK LivingLab**

A remarkably large portion of the Finnish building stock consists of post-war buildings: eighty percent of it has been constructed after 1945. Only a small number of the buildings and urban environments of 1950s-1970s have been renovated, so the work that is ahead is massive. However, the main problem is not the extent of the task, but the lack of relevant knowledge of renovation methods, as well as the confusion concerning architectural and cultural-historical values of the buildings and environments of that specific period.

A project titled “MARK LivingLab” put an effort to develop solutions to these problems. In Seinäjoki they have an ongoing renovation project of the famous civic centre of Alvar Aalto, which provided an excellent laboratory for documenting the unique construction solutions, and for developing an operations model for demanding renovation projects involving modernist architecture. Also, the city of Seinäjoki prepared a new master plan for the city centre, which made it a relevant test platform for developing principles for value-judging of modernist urban environments.

The project leader was Urban Laboratory, and the research partner was the Seinäjoki University of Applied Sciences, the School of Technology, which gives education in building renovation. The other partners were the city of Seinäjoki, which is the property owner of the civic centre of Alvar Aalto, and, obviously, the city is also the official planner of its city centre. The third partner was the provincial museum of Seinäjoki, which is responsible for protecting the cultural-historical values of urban environments all over the region.

The tasks of the project were divided into three work-packages (WPs). WP 1 was tasked to collect, document and process the material, technical solutions and new operations models produced and applied in the design and construction work. WP 1 focused mainly on the renovation of the Aalto library that was completed during the MARK LivingLab project. In WP 2, basic outlines were drafted for value-judging the urban environment of Seinäjoki's city centre. In WP 3, a new maintenance-based operations model for renovation projects was developed in tandem with the construction process of the civic centre. Successes and failures were taken into account for making the model generally applicable elsewhere.

## 6. Discussion

Professor Markku Sotarauta (Sotarauta 2009; 2016; Sotarauta & al. 2007) with his team has found out that leadership in regional development processes has kind of systemic character that is better able to deal with networks and emergence. Diverse tactics have been identified, here applied to the present study:

*Mobilisation* aims at engaging necessary competencies into development processes. In concrete terms it means encouraging and motivating actors to join the process. It is important to respect the strategies and procedures the actors are used to, as well as point out how public and private interests could be combined. In the SmartStation project our research team had an optimal arena for mobilisation in the form of the workshops. They provided for a valuable forum in which to discuss the benefits of a comprehensive and shared vision of the station area, as opposed to piecemeal development that allows optimising only the interests of private land-owners. In the Puu-Hubi –project the building cluster firms were enticed by being offered education and training for improving their competitiveness.

*Envisioning* is needed for outlining a shared future of the region. Although it seems efficient to put effort on one clear vision, it is more realistic to also take into account the visions the companies and organisations have as well. Sometimes it is possible to take advantage of the tensions between different visions by identifying common denominators for creating a new and shared vision. The SmartStation project was inherently an envisioning process. The research team developed a visual method for the workshops that enabled very heterogenic participants to work together. The Puu-Hubi project was first considered merely technical and business development, but as soon as the team started to highlight the wider benefits of timber construction for local urban development, it raised a new kind of interest among the city leaders.

*Awakening of strategic consciousness* aims to draw the actors' attention to the most important development themes. One very typical way in this is story-telling. For example, in the MARK LivingLab project the team had an occasion to highlight the cultural-historical value of Alvar Aalto's civic centre in public media. A great help in catching the attention of local media was the way the

research team connected the cultural value of the civic centre to local economic development through the benefits for the renovation business.

*Framing and filtering* are the toolboxes for selecting the themes to be included in official development agendas. For being successful in this work, shared thought-models and vocabularies should be created. It is the very core of regional development work to separate irrelevant factors from the ones that have capability to really make a difference. In the SmartStation project the team introduced the concept of “island of agreement” (Hynynen & al. 2014) to illustrate the importance of the stakeholders’ commitment to a shared vision of the area.

*Coordination* means what it says: gathering together different projects and actors for exerting stronger effects and benefiting from synergy. However, single projects do not offer positions and arenas for a research team to this kind of action. Real coordination requires an official mandate to control regional actors of different institutes and organisations. Researchers can always make initiatives and try to engage, for example, the university centre or the regional council, but from this point on the officers have a say.

*Entrenching* is somewhat easier, even for researchers, but not by using formal power. Instead, they can launch follow-ups for projects. If some useful action prevails long enough in the area, it creates routines and long-standing practices that gradually start to seem necessary and even indispensable. All the cases presented above have different spin-offs. A good example is the European13 architectural competition that was launched due to encouragement of the SmartStation results. The Puu-Hubi project influenced the founding of the new professorship on timber construction in South Ostrobothnia. The project of MARK LivingLab was continued in the form of a new project that deals with renovation, but this time at the Nordic level. The project includes renovation cases from three countries. The Finnish case is Alvar Aalto’s civic centre in Seinäjoki.

## 7. Conclusions

Research and development projects are the research teams’ medium to participate in regional development. The projects, in a way, “license” the researchers to network and create contacts, organise workshops and seminars, as well as produce material for public discussion. The use of the media makes it possible to focus public attention to certain regional resources that might be of unique quality, but too mundane for local people. A good example is Aalto’s civic centre. Put in another way, the results of the projects are not the only way to have impacts on a local level, but the projects as such are as important, sometimes even more important.

In the previous section there was a remark about researchers’ capabilities to coordinate extensive and heterogenic development assemblages, for this requires positions in official development organisations: in the regional council, university centre or in the city of Seinäjoki. However, these institutions can be included in the research team’s network, where the researchers are able to use their expertise.

In comparison to an academic operations environment, the thematic spectrum is wider in this case. Yet the work has to be theoretically informed due to the demands of the academic background community. Only the scientific credits from peer-reviewed publications and theses justify university funding. Here also lies the Achilles heel of region-based research work. Although the majority of the everyday work of the team consists of applied research, development work and networking, this part of the task is

totally ignored in the credit systems of universities and their national funder, the Ministry of Education and Culture. Nevertheless, the projects have to be launched keeping in mind the regional and local starting points. This makes the theoretical work very laborious, as there are minor chances to focus on limited conceptual horizons. From the academic standpoint, thematically broad conceptual palettes are not as appreciated as more limited and deep-diving.

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# **A Framework for Designing Responsive Architecture: A Design Studio Approach**

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## **Abstract**

Advancements in robotics technology combined with the demand for sustainable and user friendly environments have drawn attention from designers towards responsive architecture. However, a large number of experiments tend to be at the scale of art installations because of various obstacles. The objective of this research is to understand the challenges and opportunities of responsive architecture and describe the author's research and teaching explorations for designing such responsive applications. Through literature review common considerations of designing responsive architecture are mapped. Examples from the author's teaching show how digital and physical modelling and prototyping processes are interrelated with each other. The goal is to illustrate how responsive tectonic implications, digital design tools, and non-traditional knowledge boundaries are increasingly becoming assimilated into the architectural domain.

**Keywords:** responsive, prototyping, physical computing, smart, robotics

# **1. Introduction**

An increasing number of projects have drawn attention to the emergence of responsive architectural applications that show various degrees of intelligence and new tectonic effects. Several architectural researchers and designers have examined the aesthetics of such architectural kinetics and have proposed taxonomies and design methodologies for this paradigm. Moloney (2011) offers a framework for architectural facades based on analytical diagrams and time-lapse images of dynamic and animated surfaces, suggesting a shift from designing the static architectural facade to an adaptable and interactive process.

The variety of relevant terms used in research and practice – pervasive computing (McCullough, 2002), interactive architecture, responsive architecture, transformable design and architectural robotics (Green and Gross, 2009) – illustrate the multidisciplinary aspects of robotic architecture. Fox and Kemp (2009) classified projects by practical needs such as environmental sustainability, aging, changing lifestyle patterns, new sensual experiences, and discussed kinetic methods such as folding, sliding, expanding, shrinking, and transforming in size and shape, and means for actuation such as pneumatic, chemical, magnetic and electrical. In this paper, a literature review and the author's research and teaching strategies of responsive architecture are examined towards developing design methods of process-driven kinetic constructs.

# **2. Research Approach**

The objective of this paper is to offer insights into the barriers and opportunities of developing responsive architecture. The paper begins with a background section that defines the scope of responsive architecture explored in this paper. A review of relevant precedents follows to outline the challenges and opportunities. The next section describes the design process and tools used for designing and prototyping responsive architecture with examples from the author's research and teaching. Aspects of design activities, workflows, evaluation, and the role of virtual simulations are discussed.

# **3. Background**

Responsive architecture can cover a wide range of applications from large urban scales to building skin applications and small scale installations.

Moloney (2011) reviews a range of spatial kinetic precedents and categorizes operable structure, kinetic screen, surface, and other kinetics. He lists operable or kinetic structures such as the umbrella-like structures by Güçyeter, pneumatic responsive structures by Kaas Oosterhuis, and folding/unfolding structures by Chuck Hoberman. Kinetic screens involve motion of translation, rotation and scaling. Examples include adjustable louvers, rotational screens, or small shutters. Oftentimes the purpose of these systems is to track sunlight or provide shading, and the systems are operating on pneumatic, electromagnetic, mechanical actuation. The surface category considers surfaces that operate as relief such as the undulating Hyposurface by dECOi, or Flare façade prototype by WHITEVoid, and animated relief by Ned Kahn. These systems are driven by

pneumatic pistons or motorized rotations whereas Benjamin and Yang have explored shape memory alloys in gill-like apertures creating undulating surfaces. Moloney also categorizes other kinetics schemes that do not fall into any of the previous three types such as Stephen Gage's wall-climbing robots, or the Zaragoz Digital Water Pavilion, or Diller and Scofidio's Blur Building of water mist at the world media expo at Lake Neuchatel in Switzerland.

Chiu (2009) characterizes tectonic themes of responsive architecture by lightness, morphing, modes of activation, and networking modes to relate materiality, construction techniques, and responsive mechanisms. He lists projects that integrate responsive lighting patterns (Toyo Ito's Tower of Wind), integrated media displays (AG4's T-Mobile Bonn Headquarter's LED media façade), or sprays of water (Blur Building by Diller and Scofidio), and dynamic shape changing surfaces and structures that communicate information or interaction such as the Hyposurface by dECOi, oframBFRA's flexible and pliable structures presenting transformable physical surfaces. Remote social interactions can be facilitated by embedded video walls, and virtual spaces can augment physical counterparts such as the Delft University based hyperbody prototype. Various sensing and activation patterns can involve human participation, ambient environmental information and result in diverse actuation patterns.

Other categories of kinetic surfaces are built with engineered materials, such as a homeostatic façade system integrating engineered dielectric elastomers-based ribbons sandwiched into a double-skin glass façade to adapt to sunlight and temperature variations<sup>2</sup>. Klooster (2009) reviews architectural applications of smart surfaces which are taking advantage of nano-technology to respond or produce energy, light, and climate.

Pask (1969) and Frazer (1993) led design investigations of cybernetics in architecture exploring the notion of homeostatis, reflexivity and emergence which are important in the design of control systems of kinetic architecture (Moloney, 2011).

A growing number of architectural educators have explored design and teaching approaches for responsive architecture. Grinham and Ku (2012) investigated the potential of interactive architecture integrating virtual and physical spaces and described their prototyping approaches. Davis et al. (2011) describe a teaching method using input-process-output diagrams and parametric modelling to prototype responsive architecture. Meyboom et al. (2010) studied the impact of collaborations between architecture and mechanical engineering students to design responsive architecture applications.

### **3.1 Opportunities**

Many examples have demonstrated the possibilities for novel interactive aesthetics and tectonics in building skins or art installations. Involving motion, morphing of shape, color, perforations, etc., responsive architecture can engage and educate humans about changes in the environment or the relationship to other humans and the building. Sensing technology (i.e., accelerometer) used in gaming devices such as the Xbox Kinect or Wii Remote is incorporated into wearable smart devices to sense and track user movement and offer information on user activity duration,

intensity, and sleep quality. More benefits than seen in smart devices and appliances can be achieved through architectural applications by selecting appropriate sensors, actuators combined with smart algorithms. Depending on the type of sensors, the architectural applications can be responsive to human or environmental inputs, in order to facilitate social or cultural interactions, or environmental performance. While some systems involve microcontrollers that can be programmed with different levels of intelligence and changing responses, others depend on pre-engineered smart characteristics of materials or nano-technology resulting in homeostatic, thermo- or photo-active, phase change material. This paper excludes such applications that are non-programmable.

Responsive architecture can be individual units or locally networked to exhibit swarm like behavior, or linked over the internet with other systems (i.e., the internet of things), in which case the collective intelligence of systems and humans can be harvested. The vast data collected via kinetic systems, can offer feedback on user behavioral patterns, environmental performance, and assist analyzing building performance as part of a regional network of neighborhoods. Self-learning algorithms have the possibility to recognize patterns over time and offer suggestion for improving the relationships between the user, the environment, and the architectural system.

### **3.2 Challenges**

At the same time, these opportunities pose challenges to the architect and students. Robotics technologies offer new tools for the designer to understand the dynamic relationships between the environment, the user, and the architectural systems. Using the new toolsets of robotics, the architect needs to design a process that allows identifying the relationships that are most important and helps finding adequate forms.

The primary challenges include: (1) the wide range of technologies offer endless opportunities to be embedded into various scales and scopes of the built environment. This openness poses challenges to the designer determining the appropriate applications, adequate technologies, feasibility of the new systems, and implementation challenges; (2) kinetic architectural systems require integrative design processes with new compositional systems, cybernetics, and mechatronics, which are external to the traditional boundaries of architecture; (3) the application of real-time sensing and actuating and wired or wireless connectivity requires design process and tools that can incorporate the vast amount of data. While kinetic systems offer exciting visual characteristics, without properly understanding the balance and relationship between the user, environment and the architecture, the solution may be reduced to an artistic installation.

As outlined above, a few architectural researchers have focused on classifying applications (Fox and Kemp, 2009) or defining tectonic implications of kinetic or responsive architecture (Moloney, 2011; Chiu, 2009). However, there is a general lack of frameworks that integrate process and product of responsive architecture into architectural design and teaching. The next sections explain the authors' design research and teaching efforts attempting to establish approaches and frameworks that would help addressing these challenges.

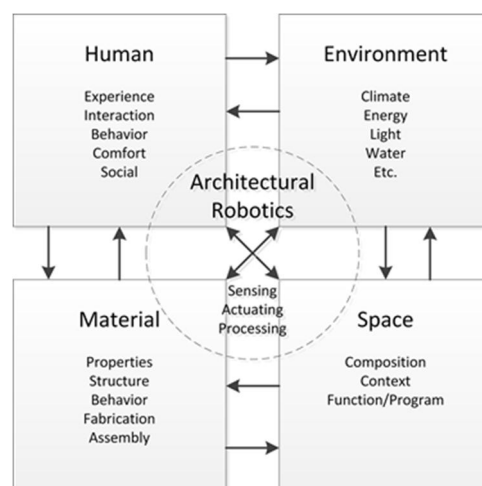
## 4. Design Research and Teaching

The author started in the spring of 2010 design research and has taught over the past four years design studios focusing on architectural robotics. Each year a different topic has been selected to facilitate the students' investigations in order to identify potential areas to be studied, to define and develop knowledge of key robotics technology, and to establish prototyping approaches:

- 2012 Spring Design Studio: Responsive bus/train shelter (architecture students)
- 2013 Spring Design Studio: Responsive building skin (architecture students)
- 2014 Spring Design Studio: Smart campus interventions (architecture & industrial design students)
- 2015 Spring Design Studio: Smart home of the future (architecture & engineering students)

These studios were taught in one semester typically divided into two parts starting with skill-building of robotics utilizing the Arduino microcontroller and Processing or Rhino Grasshopper/Firefly programming interfaces, followed by applying those skills to a team project involving design and prototyping for an architectural design.

Figure 1 illustrates a framework overlaying architectural robotics on a framework developed by Hensel (2010) for performance-oriented architecture. Four agencies are redefined, reinforced and rearranged with the integration of robotics. This framework is useful in mapping four domains that effect architectural design processes and helps to explain the relationship of architectural robotics to those four domains of agency. Accordingly, the architectural design process needs to identify the relevant aspects that can be enhanced through the application of architectural robotics and define a process to integrate and implement the new technologies.



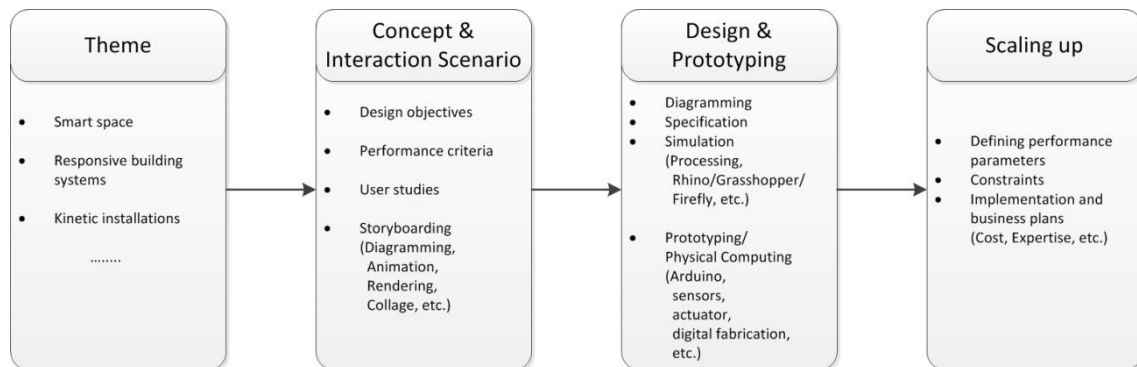
*Figure 1: Four domains of agency reconnected through architectural robotics (adapted from Hensel (2010)).*

Adapting the framework of Hensel (2012), the design of kinetic architectural surfaces can be structured as a matrix of interrelated design techniques with embedded feedback loops. The matrix can be entered from any point. The human subject would involve a process of defining

user values, needs, experience expectations, and interactions (i.e., social, architectural, environmental). Such investigations align with industrial design strategies which attempt to identify specific market needs.

Figure 2 illustrates the author's process map used for his own design research and studio teaching. Thematic explorations such as responsive building skin, kinetic shelter, smart home, or smart campus, provide the context within which specific spatial applications, site, and program, can be established. In a studio setting the larger theme is typically assigned by the instructor. Within the theme, the next step involves establishing design goals through needs assessment and investigations to develop the concept. The spatial, environmental and human domains are studied to select, define and refine site, program, and the need for responsive applications. Architectural concepts and interaction scenario are developed through storyboarding, animations, and feedback through user experience testing. Environmental agency of the natural, social and cultural agents, are conceptually diagrammed and become part of the architectural concept.

*Figure 2: Design process map for kinetic architectural surfaces.*



During design development and prototyping stages, the qualitative and quantitative input and output values are parameterized, codified to be processed by the microcontroller of the kinetic system. Virtual and physical simulations are used to learn from the environments. The material domain involves form finding processes for the kinetic constructs. Through physical experiments material properties and behavior and geometric arrangements are studied.

In addition, parametric modelling tools and simulation tools are brought in to support development, analysis and fabrication of kinetic constructs. Through an iterative process of simulations, material explorations, details of kinetic connections, actuation mechanisms are developed, studied, and improved. Visualizations (renderings, collages, animations) are utilized to extrapolate material developments to larger implementations, to understand and gather material and human feedback during this process. This process ultimately often starts from prototyping individual modules that are to be replicated to build a swarm of units that show collective intelligence in an architectural context. Typically the tectonic implications of the constructs and the architectural interfaces are an important feature of the design development process. The kinetic construct incorporating the sensing and actuating components, demand programming (Arduino microcontroller and visualization interfaces, i.e., Processing, Rhino Firefly) to refine the intelligence and behavior of the responsive system.

## 5. Student Project Examples

The studio is offered as a fifth year spring semester studio in an accredited undergraduate architecture program. As part of the studio, students learn through weekly workshops various digital tools including Processing (a visual programming tool), Arduino programming and circuits using sensors and actuators, and research additional applications such as Firefly. In earlier years, students are taught other tools including Rhino3D, Grasshopper, 3D Studio Max, and skills in visualization, diagramming, and rendering. These skills help them to define and represent user experiences and interaction scenarios which involve storyboarding and visualizations, gathering user feedback and defining design specifications for evaluating project success.

The following stages involve implementing kinetic mock-ups which integrate the use of rapid prototyping and digital fabrication tools. Kinetic constructs are an important medium in their design explorations which progress through iterations of physical models to Arduino controlled models with sensors and actuators. When possible, the studio has collaborated with industrial design or mechanical engineering students and faculty to complement necessary knowledge and skills of kinetic architecture. Each year, in the studio context different architectural themes have been provided by the instructor. Examples include responsive façades, kinetic shelters, smart campus interventions, and smart home applications. The application can be for retrofitting existing facades, interior shades, outdoor spaces, or designing new buildings.

The themes can be concentrated on specific components such as a responsive façade or kinetic shelter, or be more open-ended designs such as smart campus or smart home which require identifying and defining application areas within a larger design problem. Within the studio context, the students are tasked to select a site for their projects. Table 1 lists the project teams and project titles and schemes proposed by students for the spring 2015 semester which explored responsive architecture concepts for the ‘smart home of the future’.

The descriptions of the projects provide a brief overview of the specific functional programs defined by the students within the context of the future smart home. These concepts are developed through research identifying a specific site and defining market needs that demand or justify the application of responsive technologies. These concepts either involved remodeling of existing buildings or new construction. Another possibility is the application of smart systems that integrate spatial systems with wearable technologies such as the scheme for assisted living. Such applications require the development of various user interfaces which require different approaches than facades or spatial partitions. While the students were allowed to choose their own applications for a smart home, the table shows that six out of seven teams decided to design kinetic daylighting and/or shading systems (i.e., ceiling, screen, skylight), and only one team chose to work on an assisted living system. This illustrates that the majority of students considered kinetic systems to be beneficial and viable in improving the traditional daylighting or shading issues of residential spaces.

*Table 1: Spring 2015 project teams, titles, and schemes*

<i>Projects Title</i>	<i>Team members</i>	<i>Description</i>
<i>Canvas</i>	<i>Kevin Ryan*, Andrew Cook*, Emmanuel Nyinaku**</i>	<i>Interactive ceiling for deep warehouse remodeled into residential spaces that adjust to optimize daylighting</i>
<i>Responsive veil</i>	<i>Anne Amisola*, Marie Stefan Lesiuk*, Mathew Germani**</i>	<i>Responsive exterior screen to control daylighting and views</i>
<i>Assisted living system</i>	<i>Bong Hei Wong*, Bruce Garnett*, Devin Bachurski**</i>	<i>Responsive living system that evolves with the inhabitants as they age</i>
<i>Slide</i>	<i>Iulia Cazan*, Matt Otricelli*, Thomas Attamante**, John Fredericks**</i>	<i>Exterior shading system for high-rise buildings facilitating daylight and view control</i>
<i>SMARTrowHouse</i>	<i>Mateusz Plewa*, Emma Lindsey*, Brandon Capone**</i>	<i>Integrated artificial ceiling lighting system for deep row home spaces that optimizes user control and daylighting</i>
<i>Mimosa Wall</i>	<i>Ha Pham*, Christian Kaulius*, Parth Patel**, Nail Rachad**</i>	<i>Interactive wall screen creating for shading and exterior wall patterning</i>
<i>Flex space</i>	<i>Matt Fisher*, Brent McDonnell*, Wade Cassisi**</i>	<i>Responsive skylight system for solar and shading control in row houses</i>

\* Architecture student

\*\*Engineering student

As the program, site, and massing concepts evolve, the design focus shifts to refining interactive scenarios and the specific applications of responsive systems and kinetic constructs. Interactive tools such as Processing and Grasshopper/Firefly support visualizing and studying the behavior of interactive systems in response to environmental and human inputs. About half of the design effort is spent developing a functioning prototype or mockup which incorporates real-time sensing and actuating devices and a microcontroller. Students often develop novel mechanic systems to implement motions of responsive components such as kinetic shading systems. The development leads to understanding the swarm behavior of individual modules and finally the understanding of the issues of scaling up from a prototype to a fully functioning prototype and final commercialized product. Below are a few examples that show some of the design development aspects of other studio years. The spring 2013 studio focused on designing responsive building envelopes for high-rise buildings, and the spring 2014 studio concentrated on improving existing University campus exterior and interior spaces.



## 5.1 Responsive Building Skin (spring 2013)

Figure 3 is a student project focusing on retrofitting the building skin of a residential high-rise in Philadelphia into a responsive shading screen. The site and building were selected by the students. The students developed animations in 3DS Max to study the kinetic pattern of the entire façade and interior renderings to evaluate the impact on daylighting. The prototype development involved multiple iterations to define the mechanisms of translating the rotation of a standard servo motor which rotates only 180 degrees into linear sliding motion of expansion and contraction of circular shading module. The modules were then assembled into nine identical units which were programmed to show a pre-programmed patterning sequence of contraction and expansion, and responsive actuation to adjacency sensors (infrared sensors) and photocells to respond to change of daylight conditions.

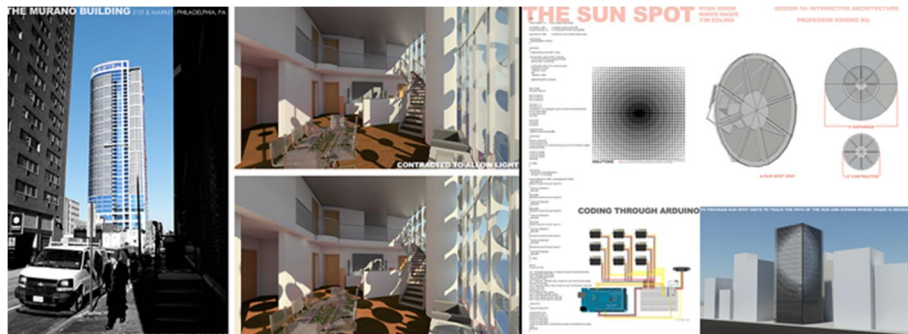


Figure 3: Responsive building skin retrofitting (by Nikos Nasis, Ryan Sison, Timothy Edling).

## 5.2 Responsive Interior Shading Screen (spring 2014)

This project aimed to transform the Philadelphia University campus into a smart campus. The team selected the Student Center common area and introduced a sun shading screen which interactively lights up based on the social interactions happening in the space.

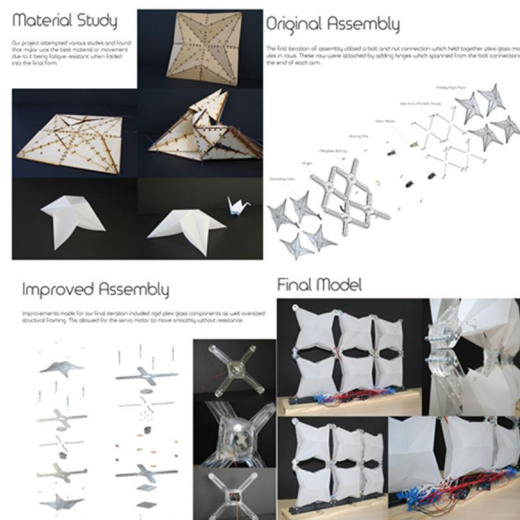


Figure 4: Kinetic construct form finding studies (by Ryan Doll and Brandon Lansing).

The system responds to users via embedded floor pressure sensors and LEDs and the shading components are activated by photocells. Figure 4 shows iterations of the kinetic construct and assembly. Form finding started with the mock-up. The overall scheme and concept was developed through sketch and renderings, followed by scale models to first develop a kinetic construct that was manually manipulated. Once material properties, behavior and assembly logics were understood, the construct was equipped with sensors and actuators connected to a microcontroller.

There are a variety of open source programmable microcontrollers (e.g., Raspberry PI, LaunchPad, Arduino). The studio adopted the Arduino platform as it provides an easy to adapt off-the-shelf platform which is built on top of the open source Processing language. Arduino and Processing are compatible with USB serial connectivity to the computer, and the Rhino3D Grasshopper Firefly plug-in. The Arduino can directly accommodate various sensors, and connect via the computer to camera, Kinect, or the internet.

## **6. Conclusions**

This paper discussed various methods and frameworks of responsive architecture. Literature review shows the variety of kinetic effects available with current technology and the cross-disciplinary characteristics involving cybernetics, robotics, mechatronics, etc. Simultaneously, the author's research and teaching illustrated the applicability of such existing frameworks and differences in academic settings. Existing literature offer points of departure and valuable precedents for studying tectonics, kinetic patterns, cybernetic control systems, and understanding of the interrelationships between technology, architecture, behavioral aspects, and material production. The literature review highlighted the gap of design frameworks for kinetic architecture. There were questions about how to do identify and design for the many possible applications in the built environment such as specific building systems (i.e., building envelope), or specific spaces (i.e., residential, commercial), or urban scale vs. building scale.

In comparison to applications in practice, a number of issues to be addressed in the academic studio environment were discussed in detail: (1) the importance of spatial theme and concept generation in student projects. It is important to offer design problems beyond the constraints of a kinetic building façade to allow students examine the broader implications of kinetic technology. When architecture students are exposed to microcontrollers, sensors, and actuators, the technological excitement sometimes drives the architectural concepts towards a specific technology such as the use of a Kinect sensor or EEG sensor rather than carefully identified user needs and experiences. (2) Higher order cybernetics concepts beyond homeostasis, towards reflexivity, and emergence are difficult concepts for architecture students to apply and implement. Students need to be exposed to such computational concepts earlier in the curriculum. (3) There are benefits and needs for collaboration with students and faculty from mechatronics, industrial design, psychology, etc. Through personal experience, such collaborations require careful coordination to align and bridge the rational boundaries of the disciplines. (4) The impact of open source software, hardware and examples. The Arduino and Processing community encourages hacking examples and the technology to learn and share new techniques and ideas with the broader community. Students are encouraged to pursue independent research beyond the

classroom to achieve their design goals. (5) The implications of prototyping: More than half of the students' semester long efforts are geared towards prototyping to design with and understand the technology, and the impact of time-based interventions. Programming, applying sensors and actuators, parametric design thinking and time-space relations of kinetic systems determine complex system behavior over time. While designing dynamic environments requires architects to rethink their role and the role of computing in design, the shift indicates that non-traditional knowledge areas can be and are gradually assimilated into architecture.

## Endnotes

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## Acknowledgements

Student project illustrations are credited to the students.

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# Community stakeholder perspective on construction industry-related needs and skills for enhancing disaster resilience

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## Abstract

Although scientific research community has shown increased interest in enhancing disaster resilience of societies, yet effort at identifying the needs and skills of stakeholders affected by disasters has not received adequate attention. Therefore, the purpose of this study is to identify and assess the needs and skills of communities affected by disasters from four different countries. Community as one of the stakeholders in disaster resilience is considered as respondent in this study, due to the fact that they are on the frontlines of both the immediate impact of a disaster and the initial emergency response. Thus, identification of specific needs and skills requirement for the community in enhancing disaster resilience becomes imperative. The study adopted literature review and semi-structured interviews. The interviews were conducted with fifteen purposively selected experts in four different countries to include the UK, Estonia, Lithuania, and Sri Lanka. Data obtained were analysed using Nvivo (version 10). The study identified different needs and skills of communities related to built environment professionals towards enhancing disaster resilience. The identified needs and skills were grouped into five disaster resilience dimensions. This includes economic, environmental, institutional, social, and technological dimensions of disaster resilience of societies. These five groups were further structured into five different stages of the property lifecycle to include preparation, design, pre-construction, construction and use stages of a property development. Also, the overall identified needs and skills at different disaster resilience dimensions were filtered to generate twenty-nine major classifications of skills and needs of communities in enhancing disaster resilience of societies. This study would be beneficial to all construction professionals and other stakeholders in developing their competencies on the main classifications of needs and skills of communities identified in this study.

**Keywords:** Communities, Construction professionals, Education, Disaster resilience

# 1. Introduction

Today, it is increasingly evident that the unprecedented frequency and costs of natural disasters and the projected increase in their severity due to climate change are posing significant economic challenges and new risks for vulnerable communities (World Economic Forum, 2008). For instance, the projections of Swiss Reinsurance Company indicates that the flooding in Great Britain and Hurricane Dean in the Caribbean cost the global reinsurance industry US\$35 billion compared to US\$12 billion for natural disasters in 2006 (WEF, 2008). This is corroborated by World Bank (2013) reports that between 1980 and 2012, the estimated losses due to a different form of disasters amount to about US\$3.8 trillion. In which, hydro-meteorological disasters accounted for 74% (US\$2.6 trillion) of total reported losses, 87% (18,200) of total disasters, and 61% (1.4 million) of total lives lost. Against this backdrop, Asia-Pacific Economic Cooperation (2010) avers that the core values of a society cannot be entirely protected at all times and the disruptions are inevitable. It is on this premise that UNISDR (2007) emphasises that communities are on the frontlines of both the immediate impact of a disaster and the initial emergency response. APEC (2010) reports that economies have shifted from a protection focus to resilience focus; thus disaster resilience is gaining importance as a core conceptual approach to building capacity in economies in the disaster-prone regions to respond and recover from impacts. This is affirmed by World Bank (2013) that disaster can be reduced by strengthening resilience: the ability of societies to resist, cope with, and recover from shocks.

Therefore, in a globalising world there is a considerable interest in disaster resilience as a mechanism for preparedness, mitigation, response, and recovery. Due to this, many countries across the globe as well as many international organisations like United Nations International Strategy for Disaster Reduction (UNISDR), World Bank among others are geared efforts toward strengthening disaster resilience, and adopting policies that emphasise the importance of community disaster resilience as a priority for preparedness. For example, in 2005, 168 countries drafted and approved the Hyogo Framework for Action (HFA) at the World Conference for Disaster Reduction, held in Kobe, Japan. The HFA provides guidance for achieving a set of outcomes and results towards reducing disaster risk over ten years (2005-2015) (UNISDR, 2005). This triggered a number of studies on disaster resilience. Many of these previous studies were focused on disaster risk reduction (see Camilleri, 2006; Jayawardane, 2006; Boshier *et al.*, 2007, 2007b; Kaklauskas *et al.*, 2009; RICS, 2009; UNISDR, 2009; Mercer, 2012) among others. Few researchers also focused on disaster resilience education (see Thayaparan *et al.*, 2010; Amaratunga *et al.*, 2011; Siriwardena *et al.*, 2013; Perdikou *et al.*, 2014; Zhou *et al.*, 2014; Thayaparan *et al.*, 2015) among others. In spite of these studies on disaster resilience very few studies attempted to identify the needs and skills of communities affected by disasters (see Perera *et al.*, 2015). Having aware of this gap, this study, therefore, becomes imperative with a view to identifying the specific needs and skills requirement for the community as a stakeholder in enhancing disaster resilience. Thus, achieving disaster resilient communities require a long-term shared responsibility among the stakeholders in the wider environment. In this regard, these study findings would be beneficial to construction professionals and other stakeholders in fostering their competencies towards enhancing disaster resilience of communities at large.

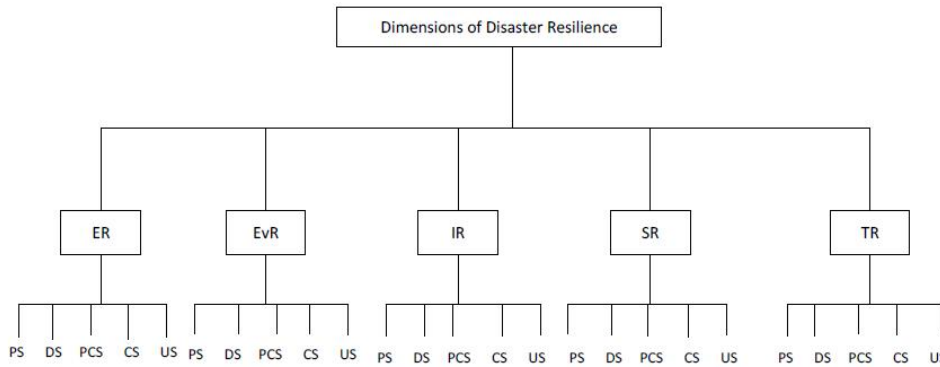
## 2. Concept of disaster resilience

The concept of resilience has received both theoretical and empirical attention across different fields. This is corroborated by Molin-Valdes *et al.* (2013) that concept of resilience has increasingly popular across academic and policy debates as a way of reducing society's vulnerability to threats posed by natural and human induced hazards. This is further acknowledged by Alexander (2013) that the concept of resilience has been widely adopted and adapted by many disciplines. Christopherson *et al.* (2010) assert that growing popularity of research on resilience is due to insecurity and uncertainty afflicting people across the world. This is affirmed by Modica and Reggiani (2015) that the uncertainty due to the interconnections between economic and environmental crises in the current global networks necessitated the growing attention being paid to resilience. Martin (2012) identifies four major reasons why researchers focusing on the concept of resilience: (i) the impact of natural and man-made disasters afflicted communities; (ii) recognition that major disruptions can affect the whole economic landscape; (iii) the influence of other disciplines, such as ecology, where the main interest is on how ecosystems respond to shocks; and (iv) the effect at both local and regional levels of financial and economic crises and their consequences, due to the austerity policies pursued by many states. Against this backdrop, Carlson *et al.* (2012) recognise the concept of resilience as a multifaceted notion that can be managed differently according to different objectives. Based on this, Modica & Reggiani (2015) conclude that researchers interested in investigating the concept of resilience more deeply may be hindered by the range of definitions, classifications and uses of resilience. This could be attributed to the fact that the term resilience has been used across a wide range of academic disciplines and in many different contexts. For instance, in physics and mathematics (see Brown & Kulig, 1996; Bodin & Wiman, 2004). In psychology expanded to include community and social resilience (see Chenoweth & Stehlik, 2001; Adger, 2000). In ecology expanded to social resilience (see Adger *et al.*, 2005; Gunderson & Folke, 2005).

Similarly, within the context of disaster resilience; resilience has been described by a number of researchers, the most common definitions of resilience relates to the capacity of a society to “bounce back”, cope, withstand, “resile from” or “spring back from” a shock (see Cutter *et al.*, 2009; Béné *et al.*, 2012). Further, Béné *et al.* (2012) and Cutter *et al.* (2008) assert that resilience has two major characteristics: (i) a capacity to recover from shocks, and (ii) a degree of preparedness. It is noteworthy to state the definition of resilience by UNISDR (2009), due to its comprehensiveness and acceptability in both industry and academia. Thus, UNISDR (2009) defines resilience as: “the ability of a system, community or society exposed to hazards to resist, absorb, accommodate to and recover from the effects of a hazard in a timely and efficient manner, including through the preservation and restoration of its essential basic structures and functions”. Concerning community resilience UNISDR (2009) further reports that: “the resilience of a community in respect to potential hazard events is determined by the degree to which the community has the necessary resources and is capable of organising itself both prior to and during times of need”. It can be deduced that community resilience is about the continued ability of a community to function during and following a disaster. Thus, there is a need for all stakeholders' contribution towards building community disaster resilience.

## 2.1 Disaster resilience dimensions

There are varieties of domains and indicators used for community disaster resilience. For instance, Twigg (2009) identifies 28 components of resilience, which are grouped into five major thematic areas: governance, risk assessment, knowledge and education, risk management and vulnerability reduction, and preparedness and response. Cutter *et al.* (2010) identify 36 baseline indicators used to measure and monitor the resilience of communities to disasters. Further, Cutter *et al.* (2010) assert that the resilience of a particular community is based on an aggregated resilience index, and therefore categorize community disaster resilience domains into five main categories including social resilience, economic resilience, institutional resilience, infrastructure resilience, and community capital. Burton (2012) identifies six dimensions of resilience, which are called variables. These include: social, economic, institutional, infrastructure, community capital, and environmental resilience. In the same vein, within the context of disaster knowledge factors (i.e. factors that enhance knowledge of managing disasters successfully) Pathirage *et al.* (2012) classify the knowledge factors into eight major categories including: technological, social, environmental, legal, economic, operational/managerial, institutional and political factors based on their characteristics. It is, therefore, evident that there are varieties of domains or dimensions used for community disaster resilience assessment. In this regard, this study would focus on five broad categories of dimensions or domains of resilience including: economic, environmental, institutional, social, and technological dimensions with their property five-stage life cycle to include preparation, design, pre-construction, construction, and use stage. This is illustrated in Figure 1 as follows:



*Figure 1: Dimensions of disaster resilience with their property lifecycle stages*

**Resilience Dimensions:** ER-Economic Resilience; EvR-Environmental Resilience; IR-Institutional Resilience; SR-Social Resilience; TR- Technological Resilience

**Property Lifecycle Stages:** PS-Preparation Stage; DS-Design Stage; PCS-Pre-Construction Stage; CS-Construction Stage; US-Use Stage

It is believed that the aforementioned dimensions of resilience with their property lifecycle stages (see Figure1) covered all the dimensions of resilience identified by previous researchers.



### 3. Research methodology

The study area, which include the UK, Lithuania, Estonia, and Sri Lanka were selected in terms of disaster impacts like the flood in the UK, Lithuania & Estonia, and Tsunami in Sri Lanka. The study adopted literature review, brainstorming session, interviews, and expert group. The outcome of a comprehensive literature review produced the dimensions of disaster resilience with their property lifecycle (see Figure 1), which form the basis of inquiry for the data collection and analysis. Thus, the outcomes of literature review were subjected to internal brainstorming comprised four researchers and academia in the built environment, which have practical experience of communities affected by disasters with a view to developing and fine-tuning the interview questions. This is, therefore, addressing potential interpretation difficulties of some disaster resilience terminologies.

Semi-structured interviews were conducted on fifteen “community” stakeholder group purposively selected from the aforementioned countries. This approach is similar to the research work by Thayaparan *et al.* (2015) that conducted ten interviews with experts in the higher educations. Purposive sampling technique is adopted because this study involved only respondents that have either experienced disaster events as a member of an affected community or respondents that were deeply involved in the reconstruction and recovery of disaster affected communities. This is supported by a number of earlier researchers. For instance, Marshall (1996) asserted that purposively sampling technique enables the researcher to select the most productive participant. Blaxter *et al.* (2006) advocated for non-probability sampling when the researcher lacks a sampling frame of the target population for the study. The interviews were conducted face-to-face, and each interview lasted between 50 minutes and 60 minutes. During the interviews, the focus was on the needs of communities, and the skills required from construction industry professionals serving these communities. Thus, the interviews were more of a discourse structured around the stages of disaster management cycle. The interviews were recorded using a digital voice recorder and notes were taken during the interviews that were conducted in the second half of 2014. Detailed transcripts were prepared for each interview, resulting in fifteen full transcripts.

The fifteen full transcripts from respective interviews were analysed using thematic coding through Nvivo (version10). During the analysis using Nvivo, the themes were presented under two major headings: (i) Needs; and (ii) Skills. The “Needs” cover both the desires and expectations of interviewees during disaster experience, and what should be in place while professionals are working with them in enhancing community resilience. Similarly, some set of skills were identified comprising those displayed by professionals involved in the reconstruction and recovery of disaster affected communities, and those desired/or expected by interviewees. Therefore, all the identified “Needs” and “Skills” were further categorised into five dimensions of resilience (i.e. Economic, Environmental, Institutional, Social, & Technological) and each of the dimension of resilience is sub-headed with the five stages of property lifecycle to include: Preparation, Design, Pre-construction, Construction and Use stage (see Figure 1). In this regard, similar identified “Needs” and “Skills” were mapped to derive classifications encapsulate the “Needs” and “Skills” of communities related to professionals towards enhancing economic,

environmental, institutional, social, & technological dimensions of disaster resilience of communities.

In addition, the derived classifications were presented to an expert group involved in CADRE (Collaborative Action towards Disaster Resilience Education) from five different countries in June 2015. These group of experts comprised thirteen professionals, researchers and academia in the built environment, which have vast experience in disaster management skills and knowledge among others. The thirteen groups of experts carefully checked and refined the derived classifications under respective dimensions of disaster resilience with their property lifecycle stages. This led to final classifications of “Needs” and “Skills” towards enhancing disaster resilience of communities. The expert group, therefore, suggested recommendations on how the aforementioned classifications can be used to update and upgrade the built environment professionals’ competencies and other stakeholders at large.

## 4. Results and analysis

The outcome of semi-structured interviews using Nvivo (10 version) for the analysis produced a long list of ‘Needs and Skills’ expected of the construction industry professionals while serving communities in disaster-related situations under the respective dimensions of disaster resilience with their property lifecycle stages. Thus, due to the limitation of space, the sample portion of identified ‘Needs and Skills’ is presented in Figure 2 as follows:

Nodes			
Name	Sources	References	
N Needs	15	1966	
S Skills	15	2113	
ER Economic Resilience	15	352	
EvR Environmental Resilience	9	301	
IR Institutional Resilience	12	387	
SR Social Resilience	12	552	
CS Construction stage	12	136	
01 Building back better	2	3	
02 Development of preventive structures and methods - flood gates, flood d	2	10	
03 Development of resilient transport networks	2	6	
04 Needs assessment and prioritisation of resources	3	6	
05 Use of local skills and resources	3	6	
06 Leadership skills	2	4	
07 Local topography	1	1	
08 Relationship with other agencies and communities	2	5	
09 Resilience planning, designing and construction	2	13	
10 Team working	0	0	
11 Time management	2	8	
12 Understanding community needs	1	4	
13 Understanding emotional and psychological conditions of disaster victims	1	1	
14 Working with the community	1	3	
15 Collaborative working	1	1	
16 Knowledge how to help people	2	4	
17 People management and Leadership skills	1	1	
18 Effective communication links	2	4	

Nodes			
Name	Sources	References	
N Needs	15	1966	
ER Economic Resilience	14	349	
CS Construction stage	13	73	
01 Assistance from external parties (i.e. govern	4	13	
02 Rapid restoration of damaged infrastructure	2	3	
03 Financial compensation for damages	3	6	
04 Funding or financing to address disaster resili	4	12	
05 Addressing the needs for resilient basic infras	1	4	
06 Financial help	2	2	
07 Business continuity strategies	6	16	
08 Providing property advise to community	1	3	
09 Access to independent professionals	2	3	
10 Alternative utility supplies after disaster	1	1	
11 Effective use of community groups and indivi	2	6	
12 More commitment from professionals	1	3	
13 Need for someone to oversee reconstruction	1	1	
DS Design stage	11	56	

*Figure 2: Sample portion of identified ‘Needs and Skills’ under the respective dimensions of disaster resilience with their property lifecycle stages*

Table 1 indicates the twenty-nine final major classifications derived from the identified “Needs” and “Skills” (i.e. after combining similar “Needs” and “Skills” like-for-like) in each respective

dimension of disaster resilience and their property lifecycle stages. Further, the final major classifications emanated in each dimension of disaster resilience with their respective stages of property lifecycle were numbered/or coded between 1 and 29 (see Table 1). For example, at Economic Resilience (ER) with its property lifecycle stages comprising Preparation Stage (PS), Design Stage (DS), Pre-Construction Stage (PCS), Construction Stage (CS), and Use Stage (US), the total major classifications emanated in each stage are 14,13,11,12,and 11 respectively (see Table 1 details).

Also, for more clarity Table 2 provides the descriptions of the twenty-nine major classifications derived with their sample portions of the identified ‘Needs and Skills’ under each major classification derived (see Table 2 for details).

*Table 1: Coding of the twenty-nine classifications into the dimensions of disaster resilience and stages of property life cycle*

<i>Dimensions of resilience</i>	<i>Stages of property life cycle</i>				
	<i>PS</i>	<i>DS</i>	<i>PCS</i>	<i>CS</i>	<i>US</i>
<i>ER</i>	1,2,3,4,9,11,14,15,16,17,19,20,23,24	1,2,3,4,9,14,15,16,17,23,24,25,26	1,2,3,4,5,11,14,17,20,23,24	1,2,3,4,9,11,14,16,17,20,23,24	1,4,8,9,11,14,15,17,23,24,26
<i>EvR</i>	6,8,9,12,15,16,25,27	6,9,12,15,16,27,10	9,12,15,27	6,9,12,15,16,27	8,9,12,15,16,27
<i>IR</i>	4,6,7,8,9,10,11,12,13,14,15,16,17,18,19,20,21,22,23	4,6,7,9,10,11,12,13,14,15,16,18,19,21,22,23,28	3,4,5,6,7,10,11,12,13,17,18,19,21,22,23	4,6,7,9,10,11,12,13,14,15,16,18,19,21,22,23,24,	4,6,7,9,10,11,12,13,14,15,16,19,21,22,23,24,26,27
<i>SR</i>	3,4,5,6,8,9,10,11,12,14,15,16,17,18,19,22,23,24,28	3,4,6,8,9,10,11,12,15,16,18,19,22,23,24,25,28	3,5,8,10,11,12,13,14,15,18,19,22,23,24,	3,4,6,8,9,10,11,12,14,15,16,18,19,22,2,3,24,28	3,4,8,9,10,11,12,15,16,19,22,23,24,27,28
<i>TR</i>	3,4,6,8,9,12,15,16,19,26,29	3,4,6,9,12,15,16,19,24,26,29	3,4,6,9,12,15,19,24,29	3,4,6,9,12,15,16,19,24,29	4,6,8,9,15,16,19,26,27,29

**Note: Dimensions of resilience:** Economic Resilience – ER, Environmental Resilience – EvR, Institutional Resilience – IR, Social Resilience – SR, and Technological Resilience – TR.

**Stages of property lifecycle:** Preparation Stage – PS, Design Stage – DS, Pre-Construction Stage – PCS, Construction Stage – CS, and Use Stage – US

*Table 2: Descriptions of the twenty-nine major classifications with their sample portion of the identified needs and skills*

<b>1. Budgeting &amp; financial planning</b> - Fund sourcing and financial management skills - Funding or financing to address disaster resilience - Financing flood adaptation strategies	<b>10. Quality leadership &amp; people management</b> - Objective consideration of issues- Flexibility - Understanding the community needs - Leadership skills	<b>19. Communication &amp; negotiation/Information systems</b> - Language (familiarity with local language) and communication skills - Effective communication links - Negotiation skills
<b>2. Quantification &amp; costing of construction works</b> - Budgeting and estimating construction costs - Pricing and estimating-Construction works	<b>11. Team working</b> - Effective use of community groups & individuals - Engaging community - Relationship with other agencies and communities	<b>20. Project audit &amp; reporting</b> - Knowledge of loss assessment and loss adjustment - Auditing skills
<b>3. Supply chain management</b> - Alternative utility supplies after disaster	<b>12. Governance</b> - Transparency and accountability in adopted processes - Minimising political interferences	<b>21. Management &amp; dispute resolution procedures</b> - Knowledge of dispute resolution
<b>4. Consultancy services</b> - Assistance from external parties (i.e. government; NGOs; Private sector, etc.) - Providing property advice to community	<b>13. Stakeholder management</b> - Clarity on roles and responsibilities of different parties - Multi-stakeholder engagement	<b>22. Cross-cultural awareness in global resilience</b> - Familiarity with local language - Use of local skills and local knowledge
<b>5. Procurement &amp; contract administration/practice</b> - Advice to community on selection of contractors and consultants - Selection of consultants and contractors - pre-qualifications	<b>14. Business planning</b> - Temporary business area - Business continuity strategies/plans - Business protection - Needs assessment and prioritisation of resources	<b>23. Project management</b> - Project management skills
<b>6. Building regulation &amp; planning</b> - Resilience planning, designing and construction - Knowledge on land-use planning	<b>15. Environmental assessment</b> - Weather changes monitoring - Awareness of potential disaster threats - Forecasting and warnings	<b>24. Asset/Resource management</b> - Use of local skills and resources - Prioritisation of resources
<b>7. Legal/Regulatory compliance</b> - Knowledge of prevailing laws, need for the flexibility of laws and policies	<b>16. Management of the built environment</b> - Development of preventive structures and methods	<b>25. Disaster management</b> - Management of disaster relief
<b>8. Health &amp; safety</b> - Temporary housing provision - Availability and identification of suitable alternative place to relocate	<b>17. Insurance</b> - Financial compensation for damages - Knowledge and awareness on insurance - Property insurance - Adequacy of insurance cover	<b>26. Risk management</b> - Disaster risk assessments
<b>9. Work progress &amp; quality management</b> - Rapid restoration of damaged infrastructure - Better infrastructure needs	<b>18. Time management</b> - Time management	<b>27. Continuing professional development</b> - Awareness & education on disaster resilience
		<b>28. Emergency management</b> - Rapid recovery after an onset of a disaster - Management of emergency shelters
		<b>29. Construction technology &amp; environmental services</b> - Knowledge on resilient construction practices

## 5. Discussion of findings

The study identified various needs and skills, which are matched like-for-like and filtered to produce twenty-nine major classifications of needs and skills expected of the construction industry professionals in enhancing disaster resilience of communities affected by natural disasters. The twenty-nine major classifications derived with their respective disaster resilience dimensions and property life cycle stages are briefly discussed as follows:

**Economic resilience (ER):** The study reveals a total of 18 (out of 29) major classifications emanated from the identified needs and skills requirements for enhancing economic resilience with their respective property lifecycle stage. Thus, the prevalent classifications include budgeting and financial planning, quantification and costing of construction works, insurance, supply chain management, consultancy services among others (see Table 1 & 2 for details).

**Environmental resilience (EvR):** In enhancing environmental resilience with their respective property lifecycle stage, the study indicates a total of 8 (out of 29) major classifications derived from the identified needs and skills under environmental resilience (see Table 1 & 2 for details). The common major classifications are work progress and quality management, governance, environmental assessment, management of the built environment, continuing professional development.

**Institutional resilience (IR):** The study shows the overall of 25 (out of 29) major classifications emanated from the identified needs and skills in enhancing institutional resilience with their respective property lifecycle stage. These include consultancy services, building regulation and planning, legal/regulatory compliance, quality leadership and people management, management and dispute resolution procedures, cross-cultural awareness in global resilience among others (see Table 1 & 2 for details)

**Social resilience (SR):** The study further reveals a total of 22 (out of 29) major classifications derived under social resilience with their respective property lifecycle stage. This includes supply chain management, health and safety, quality leadership and people management, team working, governance, stakeholder management (see Table 1 & 2 for details).

**Technological resilience (TR):** The study indicates the overall of 13 (out of 29) major classifications produced from the identified needs and skills in enhancing technological resilience with their respective property lifecycle stage (see Table 1 & 2 for details). The prevalent classifications are supply chain management, consultancy services, building regulation and planning, work progress and quality management, risk management, construction technology and environmental services.

## 6. Conclusions

Understanding and enhancing knowledge on disaster resilience among construction professionals continue to be a matter of significance and importance. Thus, identification of specific needs and skills requirement for the communities in enhancing disaster resilience becomes imperative. As communities are on the frontlines of both the immediate impact of a disaster and the initial emergency response; thus the receivers of all what other stakeholders in disaster resilience have to offer. Against this backdrop, this study identified different needs and skills requirement expected of the construction professionals across the dimensions of disaster resilience with their property lifecycle stages in enhancing disaster resilience of communities affected by natural disasters. The study, through a comprehensive desk review and selected expert group involved in CADRE (Collaborative Action towards Disaster Resilience Education) harmonised like-for-like the identified needs and skills across the dimensions of disaster resilience with their property lifecycle stages to produce a total of twenty-nine major classifications of skills and needs of communities in enhancing disaster resilience of societies. It is believed that this study would be beneficial to all construction professionals and other stakeholders in developing their competencies on the main classifications of needs and skills of communities identified in this

study. These study findings would further be useful for professional bodies such as CIOB, RICS, ICE, and RIBA to review and upgrade their existing programmes.

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# **Resilience of Inner City Real Estate Development - Challenges For The Built Environment - An Austrian Case Study**

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## **Abstract**

Urbanism and future demographic changes are demanding new approaches for contemporary city development. Cities are growing and living space in inner cities is already a rare commodity. Therefore it is necessary to understand, what it takes to satisfy the needs of future cities. Even though these problems are well known, too little new living/housing space is available and the potentials of existing inner city housing stocks often remain unused.

The objective of this contribution is to show why the redevelopment in the built environment plays an increasingly important role in the construction industry in Austria. Redevelopment can be regarded as a necessity and accompaniment of new development. With the help of a SWOT-Analysis, criteria for the redevelopment of real estate in a built environment can be identified. The results can further be combined with costs for different improvement measures of the structures and equipment of buildings to calculate its economic performance. Further knowledge can be gained for each era if the whole life-cycle-costs of the building are also considered.

Statistical surveys show that there exists a large inner-city housing stock of different construction periods in Austria. These have different characteristics and enjoy different popularities among developers and investors. The existing buildings are clustered into typical periods of similar characteristics for further research. Those are the period of promoterism (1840-1920), the interwar years (1920-1945), the post-war period (1945-1960) and the period from 1961 to 1980. The buildings from the period of promoterism and the latest construction period have the best utilization possibilities; buildings from the interwar period and the post-war period are less popular. The evaluation of the SWOT-Analysis shows that the conservation of the built environment brings economic, environmental, as well as social benefits.

**Keywords:** Built environment, redevelopment, sustainability, SWOT-Analysis, Austrian case study

## 1. Introduction

Today's society shows a trend that the population wants to live in the inner-city increasingly because of demographic changes and urbanization. For this reason, in the future the available space and the existing buildings in cities must be better utilized in order to use their potential optimally. Only in this way, long-term sustainable coexistence can be enabled in cities and contemporary urban growth can be achieved. In addition, by the optimal, economical and sustainable use of existing buildings the environment can be protected cf. (Ollig 2016).

Future redevelopment projects must be technically realizable, economical and at the same time preserving the historic values of the townscape. The energy efficiency of renovations, the accessibility and the increasingly important multifunctionality of housing stocks will pose a challenge for planning and implementation (Riehle and Kilian 2012). By lower building activities of rehabilitation of existing buildings as opposed to a new construction of a project, the use of resources and the pressures on the environment can be considerably reduced. At the same time local residents are less affected by shorter construction periods and lower emissions..

Climate change is one of the main challenges we are facing in construction industry and city development. The building sector is responsible for 40% of the total energy consumption and 50% of resources in the European Union (BMUB 2014). Energy refurbishment of the building stock is a key component of climate action plans on European level (Directive 2012/27/EU, Directive 2010/31/EU) as well as in the national implementation. In Austria the implementation aims at improving energy efficiency up to 20% until 2020. Focusing on reaching the EU targeted goals cities have a significant impact on conservation of resources, environmental protection and economic strength. Thereby the environmental impact through the demolition of existing buildings, the site equipment, transportation, as well as the construction works is much worse than those of redevelopments. In this context the question arises, how the existing building stock can be adapted for future requirements. There is a need for analytical foundations and tools to support the decision-making process of public and private stakeholders (Lützkendorf, 2016). The current paper focuses on assessing refurbishment strategies for dealing with buildings form different construction periods.

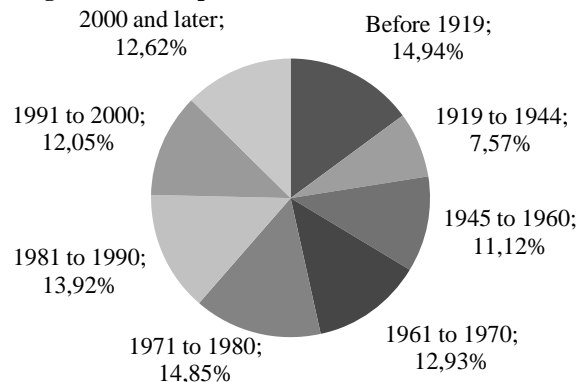
To promote sustainable development, the consumption of space must be reduced and more economic ways of city planning have to be introduced. Therefore it is important to use the available space as economical as possible by redeveloping and converting existing buildings in order to meet future society's needs and to create sustainable spaces (Passer et al. 2012).

The advantages of refurbishment are accompanied by disadvantages, which should be identified with the help of a SWOT-analysis in the following contribution. The basis of this paper is a statistical survey conducted by experts from the construction industry. Furthermore, the results were compared with the literature.

## 2. Building stock

According to statistics there are about 2.191.280 buildings in Austria (2011). Compared to the previous statistical investigation in 2001, that means an increase of 7.1 percent. The number of residential buildings even increased about 12.1 percent. In addition, about 23.500 new buildings were approved for construction throughout Austria in 2014 (STATISTIK AUSTRIA 2015). In figure 1 the buildings divided into their construction periods are indicated.

**Buildings divided into periods of construction in Austria (2011)**



*Figure 1: Buildings divided into periods of construction (STATISIK AUSTRIA 2015)*

### 2.1 Utilization possibilities

User compliance of real estate represents itself as a decisive factor for the recovery of the building stock. For a successful project development it has to be considered what types of uses can be accommodated in the future. Especially the location and building fabrics are critical influences to verify the suitable use of properties and how they can be utilized through reorganization measures. The smaller the intervention in the building stock, the less investment costs of the construction work occur.

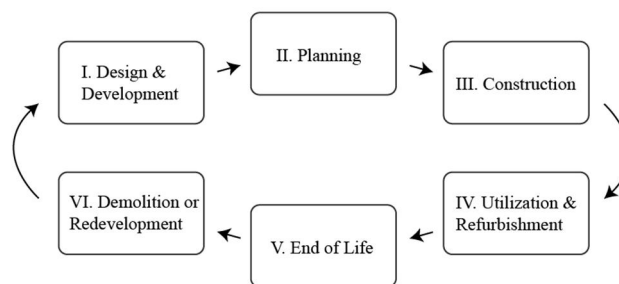
In addition to modernization, heightening, attic extensions, or annexes should be taken into consideration. Therewith coveted living and working spaces in popular areas can be created and the profitability of properties can be increased. In the progress any restrictions in construction law must be strictly observed in order to avoid unexpected complications in the planning effort (Stefan 2015, p.93).

By the mixing of functions, surface types and sizes, marketing risks can be minimized and with a flexible rental mix possible losses of rent can be countered in order to generate long-term profits with a property. Since user profiles frequently change over time, the real estate market always has to provide more flexible structures and adapt its offers for new uses through small interventions (Bielefeld and Wirths 2010, p.55).

## 2.2 Life Cycle Consideration

According to ISO 15686-5 the Life Cycle Costs are composed of construction, maintenance and end-of-life costs (German Association for Facility Management 2010, p.3). With including LCC (Life Cycle Costs) building measures can be holistically tested for their efficiency and the best long-term solutions can be identified.

Starting with the design and planning, the construction and the utilization with intermittent refurbishment measures towards to the end of the utilization, a building faces different stages of its life cycle as illustrated in figure 2. If a property has reached the end of the usage, it will be either demolished or rescheduled and reused.



*Figure 2: Stages in the life-cycle of a building*

What is already established in the conceptions of new buildings must also be used at construction sites in the built environment in the future. Only by considering all costs over the life cycle of a property, it is possible to demonstrate the cost-effectiveness of constructional alternatives. During remedial actions, for example, also all aspects of the recycling of demolition material, which are among end-of-life-costs, must gain importance for a sustainable approach. The recent standardisation activities of the CEN TC 350 related to sustainability of construction works resulted in the development of building certification schemes. Various certification systems have evolved in Europe like BREEAM, LEED and DGNB. They are mainly covering new building developments but also refurbishment activities are going to be implemented in the systems (Sezer 2014). In Austria the main certification systems are Total Quality Building (TQB), the Austrian Sustainable Building Council (ÖGNI) and klimaaktiv as an initiative of the Federal Ministry of Agriculture, Forestry, Environment and Water Management

## 2.3 Building epochs in Austria

Since the supply and demand of the built environment is versatile, existing buildings are clustered into typical building periods of similar characteristics for further research. Those are the period of promoterism (1840-1920), the interwar years (1920-1945), the post-war period (1945-1960) and the period from 1961 to 1980 (as shown in figure 1). On average, every seventh building dates from the period of promoterism in Austria. Merely every thirteenth building was built during the interwar years and every ninth during the post-war period. Finally, every fourth building was

built in the years from 1961 to 1980. This large range of existing buildings should arouse more interest among real estate developers and investors.

To judge the utilization potentials of the construction eras, a precise analysis of the building fabric is required. In practise, this often represents a major challenge for everyone involved, because often just inadequate plan material is available and it is difficult to assess the quality of the building stock in-site. Due to the different building materials and various architectural styles over time, there are specific cases of damage, which can be detected for each epoch (Stefan 2015, p.27-92).

### **3. Methodology**

#### **3.1 Definition**

To point out the advantages, but also the negative aspects about retro fitting, a SWOT-Matrix was chosen to summarize the results. It represents a systematic situation analysis, whereat strengths, weaknesses, opportunities and threats are reviewed for positioning and strategy development of organizations. Another use of a SWOT-Analysis describes the comparison of competing methods. Hereby the external field of the method is reviewed and the compared methods are confronted to identify the main differences.

The SWOT-Matrix consists of two dimensions: The internal strengths and weaknesses of the company or the method, which is dealing with its resources (finance, human resources, organization, technologies) and the opportunities and risks, which result from the external environment (competitors, technology, customer expectations, policy) (Pelz 2004, p.5). Finally creative strategies should be developed, which are derived from the analyzed characteristics.

#### **3.2 Tools**

In this application, a SWOT-Analysis was not used for an organization but to draw attention to the advantages and disadvantages of the building sector of the built environment, compared to the new development of a construction. examine the redevelopment in the built environment for all stakeholders in more detail. So a survey was carried out to examine the redevelopment in the built environment for all stakeholders in more detail. Investors, private and public owners, designers, contractors, users and facility managers have been considered in the analysis.

Although the individual building periods differ in their characteristics concerning building constructions, damage cases as well as their utilization possibilities, existing buildings were generally analyzed in the following SWOT-analysis. In individual cases, the existing properties would need to be considered in more detail and the total costs of investment alternatives would have to be weighed out with a lifecycle costs calculation.

### 3.3 Empirical Analysis

The basis for the preparation of this research is a survey which was conducted with the help of the online portal “2ask” with a sample size of 63 standardized questionnaires in the professional field of design and construction in the built environment. The mail questionnaires were sent to the Federal Economic Chambers of Styria and Vienna, to the league of Life Cycle Building (IG Lebenszyklus Hochbau), to the Austrian Real Estate Association (OVI) and to the Austrian Society for Sustainable Real Estate (ÖGNI), which all redistributed the questionnaires among their members.

In the survey, the interest of experts for the utilization of housing-stocks was evaluated (Stefan 2015, p.113). The survey results, as well as a literature review, formed the input parameters for the SWOT analysis.

## 4. Results

### 4.1 Internal analysis

The competitor analysis was performed between the construction industries "new development" and "redevelopment" in the built environment (figure 3). Emphasis was placed on the inner-city construction and the factors profitability, complexity, sustainability, urban planning, mobility, disposability, technical and legal framework, were evaluated. Mobility describes the possibility of designing the buildings accessible for all residents in this context. Based on this analysis, the strengths and weaknesses of these sectors could be shown relatively to each other.

The evaluation of the parameters was carried out with the help of a points-based system from 1 to 9 (1 = very poor, 9 = very good). The higher the rating is, the more suitable the respective property of the method. The figure illustrates the result of the evaluation.

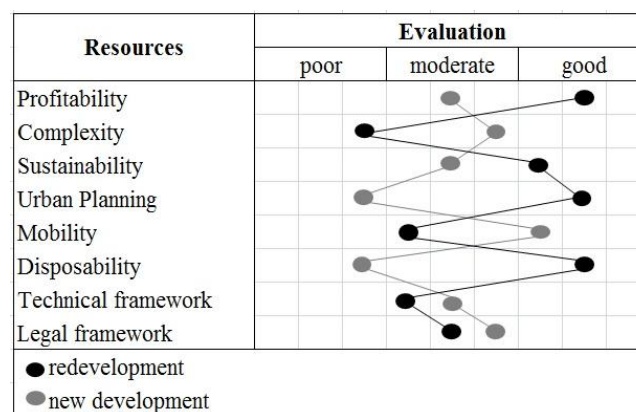


Figure 3: Competition analysis between redevelopment and new development

The analysis identifies the expected use of the building stock with the help of a strength-weakness analysis of the different eras: promoterism, the interwar years, the post-war years and the period

from 1961-1980 (figure 4). In this analysis the factors requirements, demand, building fabric, expandability, architectural style, layout, disposability, and initial costs, were evaluated.

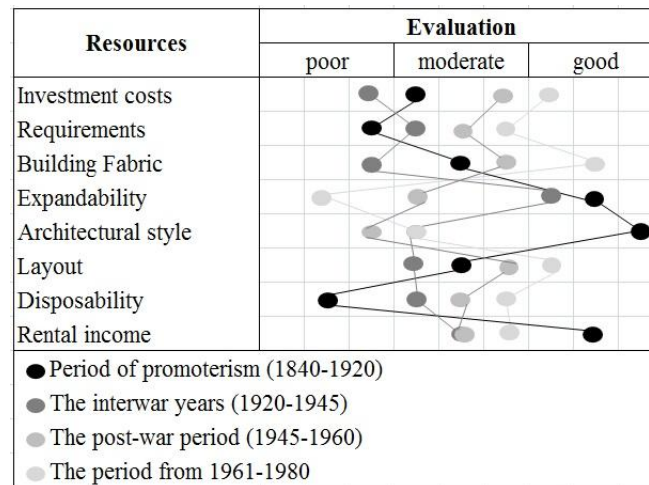


Figure 4: Competition analysis of the building eras

## 4.2 Illustration

The output of the analysis is presented by the SWOT-Matrix of redevelopment in the built environment (figure 5). Looking at the internal analysis, redevelopment scores with the following strengths: *Financial advantages*: Redevelopment has lower investment costs. Companies need less capital and can run multiple sites simultaneously. In addition you can achieve higher rental income and refurbishment is sponsored yearly with public subsidies. *Sustainability*: A holistic sustainable approach is possible by reducing environmental pollution as well as the use of resources. By manageable building activities and shorter construction periods there is less impact on the residents. Thus, economic, ecological and social aspects can be considered. *Urban-planning context*: With renovating ancient monuments; the typical townscape and historical buildings can be conserved. *Market position*: Due to the presence of a large inner-city building stock compared to limited new building sites, redevelopment in the built environment must play an important role for investors.

In contrast, the following weaknesses can be identified: *Complexity*: In redevelopment there are more insecurities and unpredictable events. Due to the many participants, time scheduling and the coordination are more complex. Redevelopment has increased requirements in planning and execution. Besides, by using the existing building structures the rental mix is harder to realize. *Political and legal frameworks*: There are many restrictions in building legislation. Listed buildings complicate the redevelopment process. *Technical framework*: The building quality of retention of old building structures is worse than new construction. There are lower potential savings achievable than in new development. The lack of information (Documentation, building plans, rate of abrasion) poses a further problem. *Structural mobility*: Structural measures that improve the quality of life and mobility of citizens are often costly and difficult to implement.

Derived from the external factors, opportunities can be seen in: *Supply and demand*: Because of demographic changes and urbanization, the demand of inner-city housing stock will increase. The built environment in rural zones may become more in demand. By heightening, additional residential units can be built in coveted areas. Also *Prospective use of housing-stocks*: Inner-city building sites are limited; many building-stocks are available. Historic buildings are on demand. Sustainable aspects will gain in importance. With the help of inner-city prestige, utilities companies can raise their reputation. As well as *financial benefits*: Through life cycle considerations, the cost-effectiveness of measures can be improved. By using certification models, attractiveness can be increased which leads to better utilization possibilities. Executive companies can use redevelopment complementary to new construction.

Possible threats can arise from: *Market changes*: The trend of the market may change and a weakening demand in historic buildings might be possible. New development is trend-setting. The inefficiency of energy refurbishment might not embrace the future requirements. Leading to *Rivalry in market*: Many business rivals are able to offer the same construction. The heavy competitive pressure can lead to price dumping. Companies wishing to enter the market might not have the necessary experience in refurbishment. Also *Political and legal framework*: Political decisions or new regulations may make the construction measure in redevelopment more difficult.

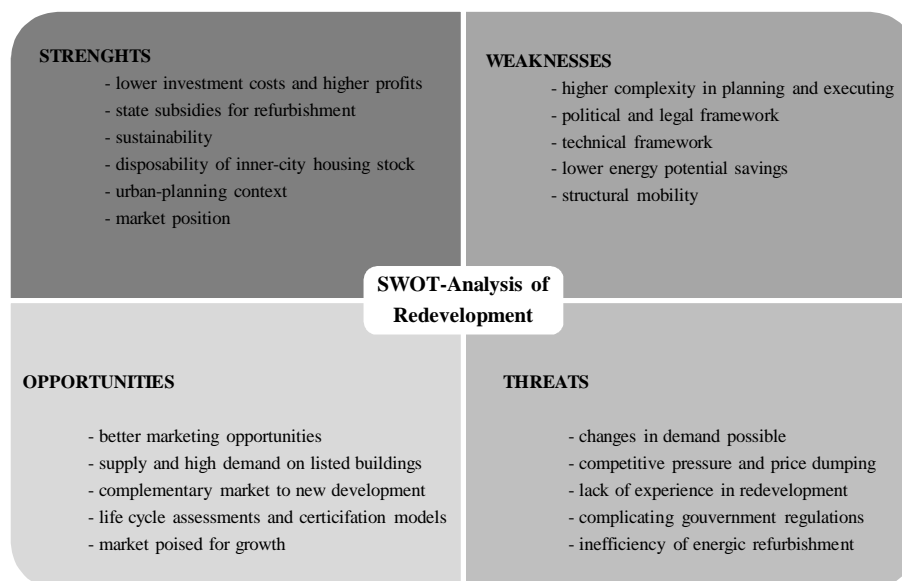


Figure 5: SWOT-Analysis of redevelopment in the built environment

## 5. Discussion

It can be said that the status quo of each building of the existing building stock must be closely examined before project launch. Only with an adequate analysis of the building fabric and an custom-tailored planning, the necessary redevelopment measures can be identified and thus the property can be successfully rehabilitated. The interfaces between all participants must be clearly defined. With forward-looking logistics and scheduling, the work of the various maintenance



groups have to be managed. According to the author the decision-makers should consider the following practices:

- § With a targeted selection of the property and an adaption to the particular benefit *investors* can optimize their rental income. Potential losses of rent can be intercepted by rental-mixes and by using sustainable certification models the LCC are minimized and marketing opportunities further increased.
- § *Private/ public building owners* can renovate several existing properties due to the lower investment costs at the same time whereby higher profits are achievable due to good demand. In addition to the development of new projects, the renovation of existing buildings forms a lucrative complementary market.
- § *Designers* must consider the political, legal, as well as the technical frameworks of redevelopments. Interfaces between planning and implementation have to be coordinated and well thought out accordingly in time to each other. Besides, attention must be paid to the accessibility of the property during the project development.
- § *Executive companies* must observe all relevant building standards and have to manage the interfaces between all maintenance groups at the construction sites by planning the logistics and scheduling. The necessary know-how must be achieved by internal staff training.
- § *Users* need to be aware of the circumstances of the advantages and disadvantages of the older housing stock and adjust their demands on the particular properties of redevelopment.

According to the experts, the use of existing buildings depends on the construction period. Although historical buildings are the most challenging buildings for renovation purposes, they are favoured by the experts due to user demand and the increased rental income. New buildings feature due to good planning documents, a short service life and modern designs also good recycling possibilities. Finally inter- and post-war buildings are less popular, but must also be recovered (Stefan 2015, p.113).

## 6. Conclusions

Considering the potential of the built environment, redevelopment has to become an important issue for the future development of cities/ urban settlement. Developing and providing flexible structures for different users will ensure the profitability of buildings. Furthermore applying a life-cycle-approach can create an additional incentive and help convincing building owners to rethinking their properties. With the help of the SWOT-Analysis, it became apparent that existing buildings have a different user demand and thus are not always equally interesting for investors. Especially existing buildings of the period of promoterism are in great demand due to the representative architectural style and yield higher rental income. Building constructions during the latest epoch can also be utilized well and show a very good building fabric due to the short working life. Buildings from the interim and post-war period are not in demand and difficult a remediation by their properties.

According to the current situation, the sustainability will be promoted by the paradigm shift in the construction industry and thus, the concomitant developments in redevelopment of the built environment will be further advanced. New ways will be found to run urban construction sites more efficiently and to reduce the adverse environmental impacts. At the same time new technologies will allow environmentally friendlier constructions. Even the recycling of demolition material must be made more effective and easier for construction companies and the accessibility of the living environment for families with small children, people with reduced mobility, but also for the increasingly aging society, will play an essential role. Here it is important that existing buildings will be adapted technically and economically as well as possible, without changing the representative appearance of the real estate.

By using certification systems, it is already possible to evaluate existing building on sustainability and to consider potential future remediation measures on their profitability. Further research is needed in the development of binding standards and guidelines. These will unify the construction measures in redevelopment and represent systematic work assistance to all participants of planning and executing.

## 7. Acknowledgements

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# **Green leasing in theory and practice: A study focusing on the drivers and barriers for owners and tenants of commercial offices**

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## **Abstract**

This paper investigates the drivers and barriers for green leasing associated with the relationship between building owners and tenants, whilst also considering the extent to which this should be considered during the life cycle phases of a building.

The procurement of appropriate rental property and its services is an important consideration for businesses. In terms of issues associated with this, few are more topical than factoring in sustainability. Emerging from this trend is a leasing product that deals with this directly. This product is a green lease. This not only impacts on the operations associated with a tenancy, but also requires a re-evaluation of the traditional owner, tenant and facilities management (FM) relationship.

Using a mixed methods approach, this paper evaluates how green leases and tenancies require a reconsideration and re-evaluation of the key drivers and barriers for the development, refit and occupancy of sustainable commercial office spaces. This is evaluated using a theoretical model that outlines the interrelation between the roles of owner, tenant and FM.

This research is based on existing literature and semi-structured interviews that studied qualitative and quantitative elements in the context of ownership and tenancy of sustainable buildings. The data collection and analysis is supported by literature research, with a focus on the provision of rental space and services in commercial office buildings with a 'Building Research Establishment Environmental Assessment Methodology' (BREEAM) certification.

This paper concludes that data gathered from practice contradicts some of the statements within existing literature, diminishing the importance of cost and the barrier of split incentive, but instead illuminate the importance of less tangible considerations such as company policy or a sustainability strategy. These findings have the potential to further develop theories, and provide an insight into how actors' relationships need to be developed to ensure more proactive green leasing of sustainable

buildings, along with where strategic attention is required during the building design, construction, operational and use phases.

**Keywords:** Sustainable facilities management; sustainability strategy; sustainable buildings; sustainable facilities and services; green leasing

## 1. Introduction

The procurement of sustainable office space and its environmentally friendly, “green”, operation is an important consideration for businesses demands on improving the sustainability of their primary activities and supporting facilities and services. Emerging from this trend is a leasing product that deals with this directly. This product is ‘green leasing’. This not only impacts on the operations associated with a tenancy, but also requires a re-evaluation of the traditional owner, tenant and facilities management (FM) interaction. The industry, from both the perspective of building owners and tenants is facing a change both in terms of their relationship, and what they expect from their buildings in terms of quality, service provision and operating costs. With considerations for greener tenancies seemingly stemming not just from supply and demand, but also from an increased need for legislative compliance associated with sustainable development (Collins & Junghans, 2015, pp 131-133), demand for sustainable office buildings has the potential to increase. Considering the significance in the rise in demand of more sustainable building stock, services and greener leasing, there is also a call to better understand the drivers and barriers for their development and occupancy.

Referring to the overall objective on investigating the innovation needs for sustainable facilities management (SFM) this paper investigates the drivers and barriers of green leasing implementation associated with the relationship between building owners and tenants, whilst also considering the extent to which green leasing should be considered during the earlier lifecycle phases of new buildings’ development or the modernisation of existing buildings. With a selection of case studies on green leased offices in the UK and Norway, the aim is to better understand and analyse the following key issues:

- 1) The drivers and barriers for organisations (primary activities / core business) in demanding sustainability and energy efficiency in their building stock and associated services.
- 2) The roles that main stakeholders in the building-life-cycle can have in the way that they impact on the sustainability of building design and construction and operation and maintenance.

The following research questions will lead the investigation of these key issues:

- What are drivers and barriers for building owners to develop and provide sustainable office space in new or existing buildings?
- What are drivers and barriers for tenants to rent and occupy sustainable office space in new or existing buildings?

This paper will consider each research question by looking both at theories based on state of the art literature analyses, as well as empirical studies based on semi-structured interviews with owners and tenants. The reasoning behind the choice of stakeholders (owner and tenant) was due to the involvement they have in developing and occupying their respective buildings. A more detailed explanation as to this research choice will be outlined in the theoretical background.

## 2. Theoretical background

### 2.1 Definitions of green leasing and sustainable buildings

In moving forward, it is necessary to understand what is meant in this paper by green leasing. Whilst Bright et al. (2014) accept that it is difficult to define such leasing, they broadly define a green lease as standard lease that also “*purposively supports and facilitates the adoption of leasehold practices that enable the improvement of the environmental performance of buildings and their use*” (Bright & Dixie, 2014, p.6). Example clauses in a green lease could be to “*agree targets and strategies to improve the Environmental Performance of the Premises and/or the Building on a regular basis*”, or “*reduction in or improved efficiency of water consumption*” (Bugden et al., 2013, pp. 14, 16 and 22). There is however no universally recognised definition, a conundrum that causes difficulties in both research and practice. In the context of tenancy, it is also important to note the context of the role of owners, tenants and FMs in an office building. This was described by Haugen (2008) who stated that owners adopt the perspective of “*value creation for the company throughout the life cycle of the building*”, the FM or building manager viewing the building from the perspective of ensuring “*that the buildings’ function optimally for their users, owners and surroundings over time*” and the user/tenant operates from the perspective of a building that “*supports their own activity to the greatest possible degree*” and “*efficiency of the building according to how it meets their own requirements per cost unit*” (Haugen, 2008, pp.15-16).

Similarly to green leasing, defining a sustainable building offers challenges in terms of a definition. From an academic perspective, a definition was offered by Berardi (2013), who concluded that a sustainable building is “*a healthy facility designed and built in a cradle-to-grave resource-efficient manner, using ecological principles, social equity, and life-cycle quality value, and which promotes a sense of sustainable community*” (Berardi, 2013, p.76). From the perspective of practice, the US Environment Protection Agency define a sustainable building as: “*the practice of creating structures and using processes that are environmentally responsible and resource-efficient throughout a building's life-cycle from siting to design, construction, operation, maintenance, renovation and deconstruction. Green building is also known as a sustainable or high performance building*” (“Green Building - Basic Information,” 2014). To this end, a so called ‘green tenancy’ can be considered to be a tenancy relationship where the activities of the users are as such that they are compatible with the sustainable credentials and infrastructure of the buildings that they possess a lease to occupy.

The definition of ‘sustainable commercial office buildings’ in this paper is referring to new and existing commercial offices with a BREEAM certification, as opposed to those directly with green leases. By new buildings we refer to them being BREEAM certified during the buildings initial development, whilst existing buildings refer to buildings with a retrofit certification. The choice of BREEAM certified buildings is due to definition concerns surrounding not just what constitutes a green lease, but also what even constitutes a sustainable building, regardless of whether it is new or existing. Using BREEAM certified buildings as a framework affords the opportunity to compare buildings through an internationally utilised and recognised certification framework that is already recognised as sustainable by many when considering its market share. Thus, using BREEAM would be an appropriate framing for the analysis of green tenancies. BREEAM has been the certification of choice in this paper due to BREEAM’s 80% European market share (BREEAM, 2015). In the UK since 2008 alone, of the 6761 individual BREEAM certificates issued 1261 of these are for offices. Their largest single certified building type is the education sector, with 1472 total certifications. These figures include both interim and final certifications (“Certified BREEAM Assessments,” 2016). In

Norway, which has only been using BREEAM (known as BREEAM-NOR) since 2011, the figures are equally as profound with offices representing the largest certified building type, amounting to 35 of the total of 54 interim and final BREEAM certificates issued at the time of writing in March 2016 ("Certified BREEAM Assessments Norway," 2016). The choice to focus on offices centres primary process similarity that is broadly pan European. Accounting for minor differences in office cultures and practices between Norway and the UK, most of their operations will be similar enough to offer comparisons.

## **2.2 Theories on what influences supply and demand of sustainable buildings and green leasing**

The emerging and growing market for more sustainable office buildings that are available for rental are a part of a change that represents an increasing move toward a more sustainable approach to tenancies (Piper, 2014, p.4). The adoption of green leases and greener leasing options such as memorandums of understanding (MOU's), is limited in scope in the attention that it receives from academics at present. Whilst data on the growth of green leases specifically is not easily available, the Sydney chapter of the Better Buildings Partnership (BBP), a collaboration of property owners working together to improve the sustainability of existing building stock, have stated that 60% of leases signed in the financial years 2012/13 to 2013/14 included green clauses, compared to 15% in 2008/09 (Bright et al., 2015, p.3). According to Bright et al. (2014), the challenge of developing more environmentally friendly leasing options to improve the sustainable performance of commercial real estate is very much an international one (Bright & Dixie, 2014, p.18). From the perspective of building owners, Wiley et al. (2008) note that there is interest in answering as to "*whether the economics of "green" design will result in higher occupancy, rents or selling prices for their project*" (Wiley et al., 2008, p.229). Looking directly at coupling trends with those of tenants, Langley et al. (2008) write that a move to more sustainable real estate is stemming from corporate social responsibility (CSR), and is manifesting in better environmental management systems and policies in buildings, which in turn may result in tenants eventually becoming reluctant to sign leases for buildings that have poor energy performance (Langley et al., 2008, p.2). Hinnells et al. (2008) try to make clear to scholars and practitioners that there cannot simply be a development of green leases that adopt a format for everyone, as "*different classes of occupiers will have different attitudes to the greening of leases*" (Hinnells et al., 2008, p.549).

From a more theoretical perspective, academic literature does note drivers that may encourage the development of sustainable buildings stock. Steward Brand (1997) for example, took a less specific but more holistic approach to this definition by stating the kinds of elements drivers could contain. He notes what he calls "*driving forces*" that shape the future environment. In the case of business, he states that this comes in the form of changes to technology, regulation, the competitive environment and the demands of customers. In the buildings themselves, the drivers are slightly more technical in nature. They also contain the technological forces noted in business drivers, but also are impacted by the economy and the use by tenants (Brand, 1997, p.182). An example of a more specific identification of factors however can be found in the work of Bansal and Roth (2000). In their paper titled 'Preliminary Model of Corporate Ecological Responsiveness', they identified the drivers of 'Legislation', 'Stakeholder pressures', 'Economic Opportunities', and 'Leadership Corporate Values/Ethical Motives' that in their eyes impact corporate ecological responsiveness (Bansal & Roth, 2000, p.718).

There is also a noticeable deficit in knowledge surrounding the development of sustainable buildings, green leases and associated tenancies, partially due to the relatively short amount of time this and

periphery issues have caught the attention of academia and practice. Häkkinen and Belloni (2011) in their research on the barriers and drivers of sustainable buildings note in their Finnish case studies and interviews, that occupants and owners are increasing their demands and expectations for such buildings, which in turn requires a development of new products and services to support this (Häkkinen & Belloni, 2011, p.250). Whilst not naming BREEAM specifically, they note that assessment tools that offer support for designers in creating sustainable building solutions are one of these services (Häkkinen & Belloni, 2011, p.247). Oyedokun et al. (2015) note numerous unsolved issues in their research on the sustainable office market in the UK, with one being of particular importance in the context of this paper. They note that a recent property boom has resulted in an increase in the development of sustainable buildings, but are uncertain if this will reflect in a long term strategic change as the boom diminishes (Oyedokun et al., 2015, p.282). This poses an interesting point of consideration for this paper, in the case of understanding whether building owners are employing a sustainable/BREEAM approach to only the building being studied, a minority of their buildings, or a prospective portfolio wide strategy. Further to this, Wiley et al. (2008) concluded in that there is deficit in the 'behaviour' of sustainable office space in national commercial markets, as well as more research being needed in what added value exists in such offices beyond simply savings in operational costs (Wiley et al., 2008, p.240).

Bond (2010) claims in her research on the Australian experience, that perceived higher costs are putting off some developers from developing sustainable buildings (Bond, 2010, p.6), despite evidence by Kats (2003) that suggests premiums on such buildings average from only 1% to around 6.5% (Kats 2003, cited in Bond, 2010, p.6). There is however no mention in the research as to whether a reduction on operating costs for example, could be a driver that could overcome this barrier. In terms of other unanswered questions on this topic, Roper and Beard (2006) offer a broad list of research needs in the realms of sustainable office studies. They cite the cost implications of sustainable appraisal, data on lower vacancy rates and tenant lease-up along with return on investment information that they claim would be of considerable use to the real estate and FM sector that is aiming actively to push for sustainable real estate (Roper & Beard, 2006, p.101).

### **3. Methodology / Research approach**

#### **3.1 Interviews with owners and tenants of sustainable office buildings**

For this research, interview participants from Norway and the UK were chosen. In the case of the tenants, they were chosen based on their occupancy of a BREEAM certified commercial office. In the case of building owners, they were chosen based on their role in commissioning the construction or refit of their BREEAM certified office, lease development and their instrumental role in procuring tenants for the property, along with being involved in the buildings management. This meant that their roles varied between being directly involved in leasing or the properties development; however their ultimate involvements in the buildings were the same. 46 potential participants were approached for study, and 15 interviewees agreed to take part over a course of 7 individual interviews and 4 group interviews with a total of 9 different buildings. The stakeholder make up consisted of 6 interviewees representing tenants, and 9 representing owners. The interviews were conducted between September 2015 and March 2016. Although the sample size is small and difficult to generalise, there is none the less scope for the preliminary results to 'shed light' on the issues addressed (Yin, 2014, p.40), as well provide scope to expand the study further.



Each of the interviewees were asked a multiple choice question regarding what factors of ‘drivers’ were important to them when choosing to develop, refit or occupy their building to BREEAM standard. The motivators reflected those most commonly found in the state of the art, both from academia and practice. They were asked to rank in order of ‘1-6’ (1 being the highest priority) the categories of **A)‘Costs’**, **B)‘A Green Certification’**, **C)‘Legislative Compliance’**, **D)‘CSR’**, **E)‘Company Policy/ Culture’** and **F)‘Industry/ Customer Demand’**.

The above drivers were influenced and informed by an extensive examination of the literature, with the previously mentioned drivers by Bansal and Roth (2000) being of particular influence. The number of drivers was kept at six in order to concentrate the results and provide a workable scope within the timeframe of the interviews, and to follow up the quantitative answers with further and deeper qualitative questions. These drivers are described in more detail in table 1.

The quantitative questioning did not deal with barriers directly; however this was covered in qualitative follow up questioning with the interviewees. Qualitative discussions were semi structured in nature, but instigated by asking the interviews to explain the narrative behind their decision to develop or occupy their building, and by asking them about what challenges they faced during their development or occupancy. Some barriers were also illuminated when the interviewees explained their reasoning behind their choice of quantitative answer. The barriers raised as a result of these qualitative responses will be discussed later in the section on the discussion of the findings.

The key aim of the quantitative results is to demonstrate the difference in priorities between building owners and tenants regarding what they most value in their respective buildings. This is the reason for the data being displayed in a division of these roles. Within the analyses of the responses, those which were given highest priority (ranking 1-3) were considered as “high priority” drivers for implementing sustainability in building development (owner perspective) and operation and use (tenant perspective). Those categories with lowest ranking (4-6) were considered as “low priority” drivers.

The following overview outlines more directly the “High” and “Low” priority factors for each of the drivers presented to the interviewee (Table 1):

*Table 1: ‘High’ and ‘Low’ priority factors for the drivers for owners and tenants*

<b>Categories</b>	<b>Description</b>	<b>Owners response: “high priority” (1-3) or “low priority” (4-6) driver?</b>	<b>Tenants response: “high priority” (1-3) or “low priority” (4-6) driver?</b>
<b>Costs</b>	<i>In the context of owners, this referred the overall business case of the development of their building with a primary consideration of operating costs (if it is the responsibility of the owner), overall building development costs, and added financial value.</i>  <i>For tenants, this referred to their outgoings in their tenancy related to rent, and utilities (if their lease makes this their responsibility).</i>	<i>Low Priority</i>	<i>High Priority</i>
<b>Green certification</b>	<i>In the context of owners, it was referring to the level of importance they placed the BREEAM certification in comparison to the other factors when developing their building.</i>	<i>High Priority</i>	<i>High Priority</i>

	<i>The same considerations exist for the tenant, with the exception of them considering how important the BREEAM certification was as a factor in them choosing to rent this particular space.</i>		
<b>Legislative Compliance</b>	<i>The meaning of this category is similar in both stakeholders' cases, in the sense that it asks the interviewee to gauge how important mandatory legislative obligations (national or international) were in their choice to develop or occupy their BREEAM certified building. This legislation could derive from the likes of local government, national buildings code, or international legislation (such as from the European Union).</i>	<i>Low Priority</i>	<i>Low Priority</i>
<b>CSR</b>	<i>Both stakeholders are asked to consider the importance of Corporate Social Responsibility (CSR) as an externally presented policy in their respective choices. CSR based decision making is also impactful on the reputation and brand image of the respective owner or tenant.</i>	<i>Low Priority</i>	<i>High Priority</i>
<b>Company policy / culture</b>	<i>This refers to the culture within the respective company or organisation of each stakeholder, and how important internal policy and cultural motivators impacted on their choices.</i>	<i>High Priority</i>	<i>High Priority</i>
<b>Industry/ Customer Demand</b>	<i>This category in case of owners refers to the degree to which demands from existing or prospective tenants influenced the development of their BREEAM building. Pressure from within their own industry is also a factor that they were asked to consider.</i>  <i>This was reflected similarly in the case of tenants, however in the context of their decision to occupy their respective building.</i>	<i>High Priority</i>	<i>Low Priority</i>

The presented interview results demonstrate difference in the driver's priority levels depending on whether they were the owner a tenant (table 1).

There was near universal consensus amongst owners that their own '*company policy/ culture*' was the most important factor in the development of their respective building, with only one interviewee valuing their '*Green Certification*' over this and having '*Company policy/ culture*' at number 2. Another building owner placed '*Industry/ customer demand*' at number 1, with '*Company policy/ culture*' at number 2. Thus, '*Company policy/ culture*' can be considered as the most important driver from building owner perspective in the context of this study. Their lowest priority was split between five owners placing '*Costs*' at number 6, with only two interviewees placing '*Legislative Compliance*' at the same placing, with one interviewee valuing '*Costs*' much higher at number 2, and another at number 3. There was less consensus on the other priorities, with three interviewees placing a '*Green Certification*' near the middle of the scale, and with two interviewees placing '*CSR*' at number 5.

With regards to tenants, there was less agreement as to what their priorities were when choosing to occupy their respective buildings. There was little consensus on the top priority, with the only commonality being two interviewees placing '*Green Certification*' at number 1. A similar lack of consensus was found at the bottom of the scale, with two tenants placing '*Legislative Compliance*' and another two placing '*Industry/ customer demand*' at number 6, representing the only commonality for the lowest priority factors. Two interviewees placed '*CSR*' at number 2 making it a "high priority"

driver, and two interviewees placed '*Costs*' at number 3., and two of the tenants placed '*Legislative Compliance*' at number 5, which might be considered as a potential "low priority" driver.

The results show that '*Costs*' are mainly valued as a "high priority" driver amongst tenants, whilst in many cases the building owners consider it as "low priority" driver, (4-6). Whilst there was little commonality amongst tenants, the interviews point towards '*Company Policy/ culture*' as being a key "high priority" driver of the development of sustainable buildings amongst owners. Amongst almost all of the actors in the study, '*Legislative Compliance*' was considered as "low priority", and placed in the lower half of the rating scale (4-6).

## **4. Discussion of findings**

### **4.1 The barriers and drivers for owners of BREEAM certified commercial offices in Norway and the UK**

The literature notes numerous difficulties in the development of sustainable buildings. Bright et al. (2014) notes how there is little incentive for building owners to install energy efficient technologies in their buildings due to the upfront costs and expensive maintenance (Bright et al., 2014, p.17). Literature also claims that sustainable building management and FM is being increasingly driven by legislation, and less so by corporate image (Casals, 2006; Ayres et al., 2007; Shiers et al., 2007, cited in Elmualim et al. 2012, p.17). The results of our study however, were indicative of the opposite. One of the British building owners for example, claimed that their investors were keen to have as many new and retrofitted high performance BREEAM buildings as possible, due to the long term financial benefits as well as those associated with CSR. This was despite the substantial upfront costs necessary to make this approach possible. Similar comments were echoed by other interviewees, all of whom cited a combination of company policy and long term financial benefits in terms of maintenance as being important factors in their investments. Despite some discussion on the contrary, an industry wide survey by law firm DLA Piper of more than 100 building developers did illustrate a consideration that was reflected in our study. DLA Piper claimed that only 3% of their respondents felt that existing or pending legislation influenced their decision to deliver sustainable real estate products (Piper, 2014, p. 17). This was reflected in our results, where less tangible considerations such as company policy were a higher priority than the likes of legislative compliance.

The key difficulties were technical and structural, with one of the Norwegian building owners, for example, being aware that their tenants were experiencing difficulties with their Building Management System (BMS). Many of the building owners also felt that the BREEAM process was overly difficult. One of the Norwegian building owners cited the frustrating lack of points received for building on an empty site and not demolishing an old property. The owners of existing buildings had experienced some construction difficulties when retrofitting their buildings, especially with regards to planning regulations. Of note was the planning restrictions experienced by one of the British building owners. Their building is a refitted Georgian building, and they were not permitted to replace the old sash windows with a modern equivalent. Although the building performs well, this they considered to be a frustrating barrier in the sustainable upgrade of existing building stock. Due to the BREEAM certification system not accounting for an issue such as this; it was a contributing factor in the building not receiving the level of BREEAM certification that was intended earlier in the buildings design phase. This is recognised by Dixon et al. (2008) referring to the point that cost effectiveness and the

social acceptance of some refurbishment and retrofitting is an ongoing barrier to sustainability (Dixon et al., 2008, p.14).

## **4.2 The barriers and drivers for tenants occupying BREEAM certified commercial offices**

Current research suggests that sustainable buildings are valued more by potential occupants due to their lower running costs, along with providing a more attractive working environment (Sayce et al., 2010, p.4), although some evidence suggest that their real world performance does not match the technical specifications (Turner and Frankel, 2008; Paul and Taylor, 2008, cited in Sayce et al., 2010, p.4). The interviews conducted so far however place the likes of costs (both in the context of 'operational' and 'developmental') far closer to the middle and bottom of the priority scale, making it less of a consideration. The majority of buildings owners associated more closely with the development costs of the their building (for which they are more directly responsible) and tenants more with operational costs, which greater impact the day to day financial elements associated with their tenancy.

Wiley et al. (2008) suggests factors that could encourage tenants occupy a sustainable building. As well as helping enhance other aspect of the business, they note that a reduction in operating costs could offset some larger expenses (i.e. rent) that a high performance building may command (Wiley et al., 2008, pp.233-234). Whilst no tenants stated that a reduction in costs was a key factor in their decision to move to their respective buildings, they were none the less aware of the positive impact on their operational costs. One of the Norwegian tenants saw a 50% operational cost reduction, achieved through a combination of the building technology and the 50% reduction in space when moving from cell to open plan offices. Another Norwegian tenant also reflected on this, saying that whilst operational costs were not a key concern for them in choosing this building, they have always pursued operational cost reductions and even went as far as to attempt a green certification of their previous premises to act as a 'toolkit' to help reduce their energy.

When pursuing the occupancy of any building let alone a sustainable one, there are inherent barriers that risk the ease of both the buildings procurement and occupancy. The literature points mostly to financial and legal barriers to negotiating these tenancies, with the likes of split incentive causing a lack of trust and an growth in tensions (Wilson & Tagaza, 2006, p.2), with one scholar going as far as to say that split incentive is "*a notorious obstacle to improving the environmental performance of tenanted commercial space*" (Bright et al., 2014, p.17). Each of the tenants was asked specifically how the negotiations went with their landlord, and if any tensions or difficulties had arisen. None of the tenants claimed to have had any such problems, even, as is the case of one of the Norwegian tenants, appreciating the ability to be involved in the buildings design and even paying for the BREEAM certification themselves at the suggestion of the owner. This contradicts a potential barrier noted in literature, that states that often adversarial relationship between the landlord and tenant that can potentially stifle the development of sustainable buildings, and their associated greener tenancies (Hinnells et al., 2008, p.544). Whilst not necessarily a tension, one of the Norwegian tenants noted that their office building had experienced problems due to the tenant not engaging enough with the owners during the buildings initial development. Poor communication during the earlier design phases resulted in a building that was, according to the tenants "*not to the standard we had expected*" and a lack of progress meetings leaving numerous design problems that are not easily fixed now that the building is in operation. The tenant went on to say that "*we are also in the process of acquiring two new BREEAM buildings and we know the mistakes not to make again. One of them is now finished and we are very happy with it, mostly because the developers and we worked as a team this time*". The

barrier of communication is one issue that the literature has recognised in these kinds of buildings (Hinnells et al., 2008, p.544), but also note that there is potential through the leasing structure to allow for “*effective channels of communication to promote green issues, and to promote day to day property use and management that takes account of environmental issues*” (Hinnells et al., 2008, p. 544), and thus go some way towards alleviating this barrier. In the literature studied for this paper however, there was no discussion on how this communication barrier could be addressed at an earlier life cycle stage. So far, all of the technical barriers relate exclusively to the buildings BMS systems, with this being a particular issue for one of the Norwegian tenants of a new BREEAM building. The integration of technology had been problematic for them to the extent that one of the tenants hired their own ‘integrator’ to help with the software implementation during the buildings development, which they felt averted larger problems. To quote the same tenant, “*developers are great at building buildings, but they need to work harder at understanding the technology they put in it and how to make it all work together*”.

## 5. Conclusion

When looking more directly at what we know and do not know about the study of sustainable offices, there is a notable need for research to pursue what is driving not just the development of these buildings, but also what drives their tenants to sign leases for them. Whilst we know that there has been an increase in the uptake of the likes of BREEAM and other sustainable certification schemes, it is unsure at present as to if this is a temporary consideration by developers, or a long term commitment for their portfolios. In the context of BREEAM certifications, there is scope for the certification to consider the drivers and barriers presented by the development of sustainable building stock, both in terms of the context of its assessment criteria and how they make the scheme and methodology more attractive to prospective clients. This paper also demonstrates to some extent the business case of these buildings from the perspective of owners and tenants, and an understanding from both stakeholders as to the operational costs savings achievable in a sustainable office building with a BREEAM certification.

From the perspective of the delivery and development of green leases in theory and practice, the results in the paper have illuminated differences between both. The literature represents a need to understand ‘value’ from the perspective of both owners and tenants beyond what has been cited in the literature. The results have demonstrated that despite what is often in literature; less tangible drivers such as company policy and CSR are of significance. There is also scope to recognise some of the technical barriers associated with these buildings, and that the landlord\ tenant relationship may not be as adversarial as was previously believed in some literature. Overall, the results demonstrate that different needs, drivers and barriers exist depending on whether attention is placed on the owner or tenant, with a need to adjust priorities accordingly. Understanding these differences not just impacts on the development of sustainable office buildings as per the questions asked in the interviews, but also emphasises the consideration stakeholders need to be mindful of when developing an attractive and achievable green lease strategy for a sustainable office building. The development of sustainable buildings relate not just their development of their physical structure, but also how attractive their leasing and policy decisions are to the tenants who may occupy them. The results in this paper have also shown little demonstrable difference in the barriers and drivers of a building whether it is new or existing.

With these concluding thoughts in mind, this paper has scope to further existing research needs by providing a better understanding as to what drives key stakeholders in sustainable office buildings

whilst also demonstrating a potential path for further research with larger samples, different focuses and the involvement of other stakeholders such as facilities managers and architects.

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The main objective of ZEB is to develop competitive products and solutions for existing and new buildings that will lead to market penetration of buildings that have zero emissions of greenhouse gases related to their production, operation and demolition. The Centre encompasses both residential and commercial buildings, as well as public buildings.

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# **The case of the AlpHouse Center in Belluno (Italy): promoting building culture and sharing know-how and experiences in an alpine territory**

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## **Abstract**

The Alps play a key role not only in the environmental and economic European scenario but also from a cultural point of view, as an example of long-term adaption to particular climatic and geographic conditions. The Alps can be historically considered a place in which the principles of economic, social and environmental sustainability were practiced before their official definition. Alpine territories and their traditional architecture can be considered a lesson from the past in terms of well tested construction techniques, careful uses of locally available resources, environmental balances and adaptation to local conditions. In the framework of the Alpine Space European Programme (2007-2013), many projects have focused on these aspects. Two in particular, AlpHouse and AlpBC, have analyzed regional building practices in the Alps in order to collect their traditional know-how, innovative content and to implement measures at different scales to preserve and advance alpine building culture. In the context of the AlpBC project, one of the activity promoted is the creation of a transnational network of AlpHouse Centers (AHC) across the Alps. The AHC are physical places, in which the results of the studies and pilot activities of Alpine Space projects are made available to stakeholders of the building sector and to the population. The goals of the AHC are those of sharing best practices in the territory and among the network Centers, promoting education regarding alpine building culture, doing interact the different figures which are involved in the territorial planning and building sectors in order to promote local identity and economic development. Considering the effort of the AHC network a significant example on the importance of sharing experiences, the paper will present the case of the AlpHouse Center of Belluno (AHCB), an initiative promoted by the Urban Planning Section of the Veneto regional authority and implemented by the Foundation "Architettura Belluno Dolomiti" (FABD). In order to analyze this experience as a best practice transferable to other contexts the paper will present the participatory work done by the regional government, Iuav University of Venice and FABD for the set-up of the Center and the start-up of its activities.

**Keywords:** Alpine Space Programme, building culture, best practice, involvement, sharing experiences



# 1. Introduction

After successfully distancing itself from the recurrent definition of less-favored area (75/273/EEC), the Alpine territory may be considered as a background to address and manage future environmental challenges and their social and economic effects. As declared by Fondazione Montagna Europa Arnaldo Colleselli (2012), "Mountain territories represent the ideal framework to test and establish a new model of economic development, marking the shift towards a resource-effective economy with lower carbon emissions and resilient to climate change. This will contribute to protecting and improving environmental quality while halting and reversing the loss of biodiversity" (page 2).

The Alps are ready to seize this opportunity. The organization of the territory and the settlements and the construction of traditional buildings have been historically characterized by the capacity to combine the requirements of the environment with human activities. This know-how has been handed down for centuries (Dematteis, 2011) and it can be re-interpreted and proposed today. Moreover, in the existing context of urban planning, requalification and building activities, the Alpine territories can therefore meet the EU directions on reducing emissions (COM (2011) 112 (2011), COM (2011) 885 (2011)) and resources consumption (COM (2014) 445 final (2014)), blending their traditional know-how with innovation in planning and building sector.

In 2000, the European Union launched the Alpine Space program for territorial cooperation dedicated to the development, innovation and sharing of experiences in the Alpine territories and the peri-Alpine belt. Within the 2007-2013 Alpine Space program, two projects specifically covered the above mentioned issues: the AlpHouse project (Alpine building culture and ecology, 2010-2012) and its continuation and capitalization ("Capitalising knowledge on Alpine Building Culture by performing regional smart planning and consultancy strategies for sustainable development and closed loop economies in the Alpine Space," 2013-2015). With reference to the priority axis of competitiveness and attractiveness, the objectives of these projects included the creation of a network of AlpHouse Centers in the Alps area (Germany, Austria, France, Italy and Slovenia) (Figure 1). These centers would become reference points for the dissemination of the building culture, sustainability and the exchange of knowledge and technologies, particularly those concerning the energetic and environmental requalification of buildings. Furthermore, their uniqueness would lie in their capacity to connect both with the local territory and with the network of AlpHouse Centers (Figure 2). The possibility of these centers of acting in the local areas and at the same time to belong to a wider network in the Alps meets the intent suggested by the Alpine Convention, in particular in its declaration "Population and Culture" (2006), which encourages community awareness and identity and, together, participation and cooperation.

The idea to establish an AlpHouse Center in Belluno (Veneto Region, Italy) for the promotion of the culture of living and building in the Alps arises from this context. The Veneto regional authority has been a partner of the Alpine Space programs on territorial and Alpine architecture sustainability for a decade. Through these same projects, the Belluno area - as a pilot area - participated in a series of territorial cooperation activities which saw the joint involvement of the academic world, public administrations, technical experts, enterprises, and members of the

building sector. All the parties cooperated within a network of experiences involving other Alpine countries to share problems, solutions, policies and good practices. The Belluno province was chosen not only for historical, cultural and territorial reasons, but most importantly because it is the only Veneto province entirely located on mountain land and straddled over other Alpine regions, sharing the homogeneous features of the Dolomites area. This condition of physical and cultural belonging has helped the implementation of a number of studies, research activities and projects on common issues, whose consequences fall on a territory and a community committed to enhancing their identity resources, peculiarities and expertise.

In order to leave a tangible legacy of this remarkable activity, capable of taking over its aims, capitalizing the new heritage of knowledge and enhancing it, the professional organizations decided to create a "permanent center for the culture of living and building in the Alps" – the AlpHouse Center of Belluno. Part of a network of AlpHouse Centers already active in Europe which have already started to set their objectives in relation to their territorial, cultural and economic peculiarities, the center would be in charge of spreading awareness among experts, operators, citizens and administrations around the issue of balancing natural resources and enhancing the local culture and economic systems.

Based at the already existing Fondazione Architettura Dolomiti Belluno (FABD), as the other AlpHouse Centers in the Alps, the AlpHouse Center of Belluno set a series of specific objectives that are relevant for its territory of reference, namely:

- protecting and developing the cultural heritage, composed of landscape, vernacular architecture, regional materials and local building techniques;
- developing knowledge of the territory and its different facets, peculiarities and constant evolution;
- enhancing and creating a network of building traditions and "consolidated expertise";
- promoting a short supply chain in the building sector;
- creating a platform to collect good practices, especially at the provincial and regional level, to be shared with public administrations, local bodies, individual citizens and, more in general, all the stakeholders in the field.

Seen as a physical space operating locally on the territory as well as part of a network of similar entities in the wider Alpine context, the experience of the AlpHouse Center of Belluno may set a standard for the sharing and enhancement of knowledge, training and territorial innovation, and the creation of opportunities, to be deployed in other contexts too. To encourage the transfer of experience which could be useful for other alpine territories, the following sections explain the methodologies and preliminary activities of the set-up of the AlpHouse Center of Belluno, the definition of the organization, and a summary of the early activities performed.

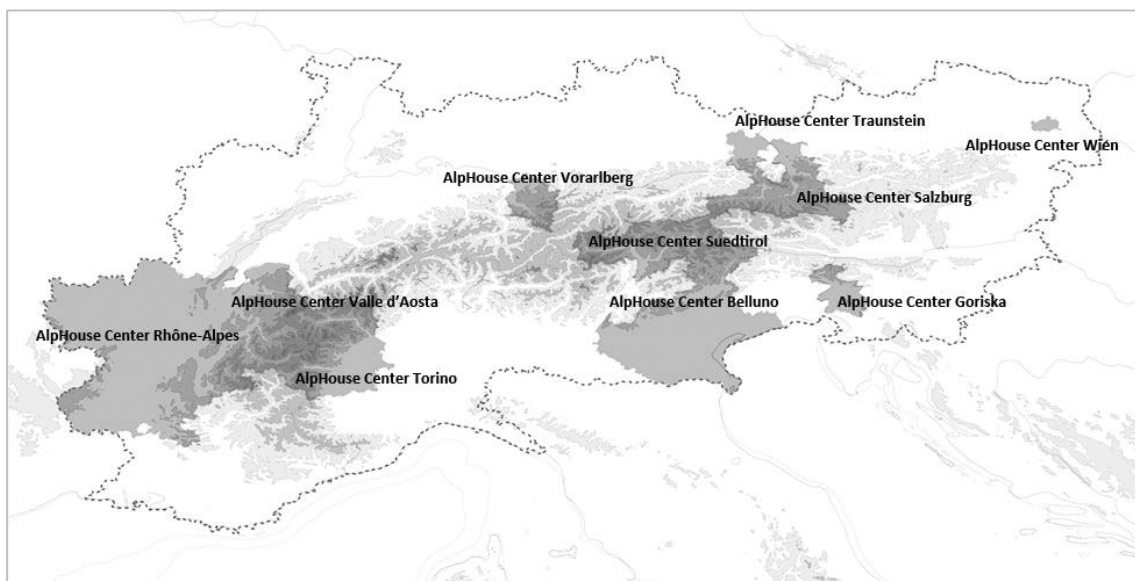


Figure 1- The AlpHouse Center network created in the Alps: together with the AlpHouse Center of Belluno, eight other AlpHouse Centers have been developed. Often they are hosted in research centers, regional offices, chamber of commerce, depending of their main objectives ([www.alphousecenter.eu](http://www.alphousecenter.eu))

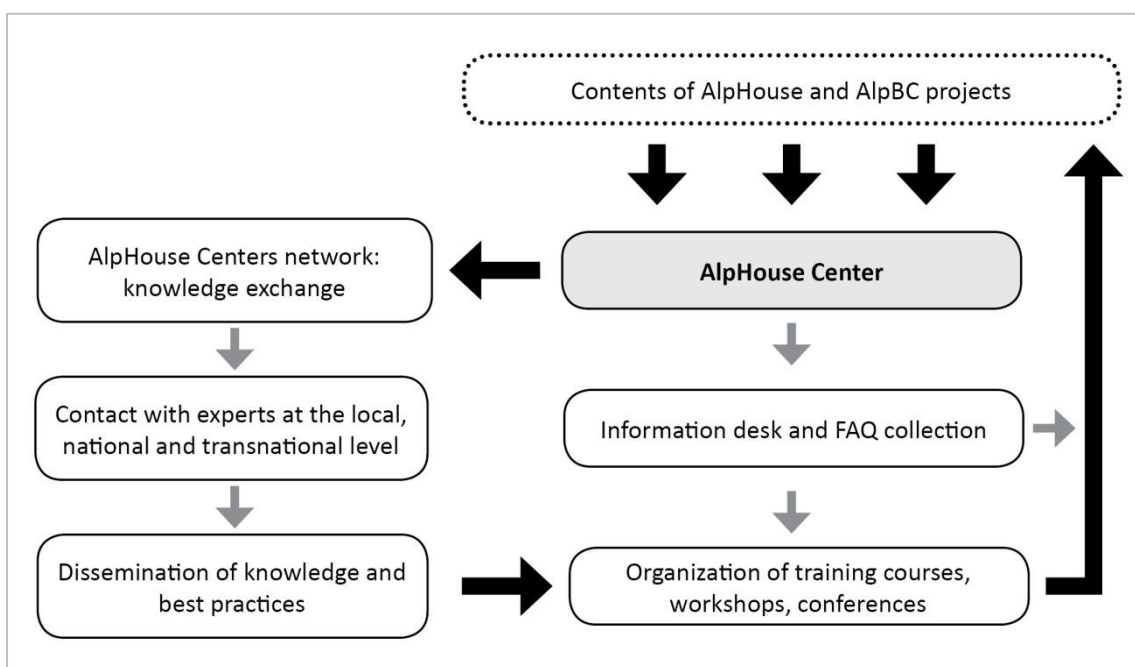


Figure 2- The operating structure of the AlpHouse Centers in the framework of the Alpine Space Programme. The AlpHouse Center network contributes on one side to act locally, with organization of training courses, workshops etc. and to share best practices; on the other side it supports research development in the Alpine context.

## **2. The set-up of the AlpHouse Center of Belluno**

### **2.1 Preparatory activities**

The preparatory phase of the set-up of the AlpHouse Center of Belluno, held between April and May 2015, began with the planning of three knowledge, discussion and investigation activities on some of the aims and priority areas among the objectives listed above. The first two activities were carried out in the form of focus groups, a technique often applied in social research work. A focus group consists in a guided discussion on a specific topic where a restricted group of participants is coordinated by a facilitator, whose task is to keep the conversation within the chosen subject. The topics of the two focus groups coordinated respectively by the Iuav University of Venice and Ambiente Italia, an environmental consulting firm, were the requalification of traditional Alpine buildings and the integration of energy-related issues in urban planning. The third preliminary activity was a study trip to another AlpHouse Center, with the participation of the subjects charged with the set-up of the Belluno center. These three experiences highlight the importance of exchanging information among different subjects, sharing good practices and adopting a participative approach, as suggested by the Alpine Convention, Declaration "Population and Culture" (2006).

For the first focus group, dedicated to the requalification of traditional Alpine buildings, thirteen participants were selected to take part in the guided discussion (Figure 3). They included planners (architects, engineers, renovators), building companies specialized in renovating existing buildings, plant engineering experts and public bodies representatives (municipalities and local action groups), all active in the Belluno area. The requalification of traditional Alpine architecture is one of the most recurrent themes in the Alpine Space European programs (as AlpCity, AlpHouse and AlpBC), as well as a relevant issue for the territory where the AlpHouse Center of Belluno is located: 44% of residential buildings in the province of Belluno have been built before 1945 (Istat, 2001) which means with traditional building techniques; to this number it should be necessary to add the rural buildings (e.g. barns and stables) which are not legally estimated yet. The involvement of different subject categories representing the various phases and aspects of the requalification process symbolized the willingness to adopt an integrated approach in handling the various issues surrounding the AlpHouse Centers. Furthermore, the collection of different perspectives among various subjects emerged as a real necessity. Indeed, requalification actions often require the harmonization of protection and conservation priorities with the existing legislative framework, the users' needs and the available technological innovations. The discussion held by the focus group led to the selection of a range of possible issues identified as priorities by the subjects operating in the sector and the territory. These may be dealt with during the next training and informative activities of the AlpHouse Center. They include statutory compliance, energy-related issues, the localization of materials and resources, the new relation between requalified traditional buildings and the mountain landscape, construction technologies, the integration of plant design, the importance of understanding the existing building, and redevelopment costs. In addition, participants expressed the need to receive training at different levels and specifically addressing the renovation of existing buildings, which confirms the purpose of the AlpHouse Center of Belluno as a training center. They also stressed the importance

of creating a network to share knowledge and good practices on the requalification of traditional Alpine architecture, an idea which has been also planned for the AlpHouse Center.

The second focus group concentrated on the territorial scale and examined the integration of energy-related issues in urban planning. Due to the nature of the issue, the focus group involved some representatives of public administrations and urban planners of the Belluno province. In addition to energy, a topic unanimously considered as critical, the discussion highlighted the need for planning activities to start addressing sustainable mobility, the quality of settlements and limiting soil consumption. Indeed, these issues could be looked at within the wider scenario of the entire mountain territory regeneration towards the enhancement of the local economic system and culture. As in the first focus group, the second group also highlighted the need of applying good practices coming from other regions and from other AlpHouse Centers, as e.g. the AlpHouse Center in Vorarlberg. Moreover, it identified information, training and consultancy as possible activities offered by the AlpHouse Center. Among the priority themes covered by these activities, the group selected sustainability, resilience and adaptation, the energy certification of buildings and settlements, the production of renewable energies and the implementation of energy planning tools.

Finally, in view of sharing good practices and experiences and creating a preliminary cooperation network, the third activity consisted in a study trip to the AlpHouse Center of the Aosta Valley (Italy). The AlpHouse Center in the Aosta valley, already in operation for some years, can be considered similar to the one being developed in Belluno. The two AlpHouse Centers share a similar alpine territory and building stock, a similar legislative background and similar objectives for their activities. The study trip involved the participation of the people in charge of the creation of the AlpHouse Center of Belluno in some discussion boards for planners, companies and local administration of the Aosta Valley territory (Figure 4). The discussed themes included the restructuring of public buildings, the energy optimization of public lighting plants, the production of renewable energies, and the financing and enhancing of energy requalification projects, identified by the AlpHouse Center in the Aosta Valley as priorities for its territory of reference.

The three preparatory activities for the elaboration of the training program of the AlpHouse Center of Belluno had three main objectives. The first was to identify a preliminary list of building and planning-related issues perceived as relevant by those living and working in the Belluno area. The second was to test a number of modalities for a participative approach to activities (focus groups, discussion boards, etc.) and to set operating standards for the upcoming AlpHouse Center of Belluno. Finally they offered a chance to enter into contact with possible future interlocutors already active in the territory, and with other AlpHouse Centers, as e.g. the one in Valle d'Aosta.



*Figure 3- The focus group in action during the first focus group related to the refurbishment of traditional buildings.*



*Figure 4- Different discussion boards during the study trip at the AlpHouse Center in the Aosta Valley.*

## **2.2 The organization of the AlpHouse Center in Belluno**

Based on the themes emerged from the preparatory activities, which have been combined with the specificities of the territory and the experience of the promoters of the AlpHouse Center initiative (Veneto regional authority and Fondazione Architettura Dolomiti Belluno) the main characteristics of the AlpHouse Center of Belluno - a permanent center for the culture of living and building in the Alps - have been defined (Figure 5). The priority themes, the target groups of the activity and the type of activities have been outlined as follows.

As regards the choice of the priority themes, the purpose has been to combine the specific needs of the territory (including the conspicuous presence of buildings to requalify and the specificity of a mountain area) with innovation and sustainability, in order to insert the activities of the Center in the context of a coordinated development at European level. The main themes defined by the AlpHouse Center of Belluno and the reasons of their choice are therefore:

- European-planning, especially related to the field of the culture of living and building in the mountains, in order to match the priorities set by Alpine Space Programme with the activities to develop in the Belluno area;
- Restoration and conservation of the architectural heritage, related to the specificity of the building stock in the Belluno area;
- Architecture and technology, as a theme which can combine tradition with innovation and involve the building sector;
- Sustainability, in order to fulfil national and European targets and to re-interpret traditional constructive know-how;
- Environment, landscape, urban planning and governance, in order to manage the development of the territory at different scales.

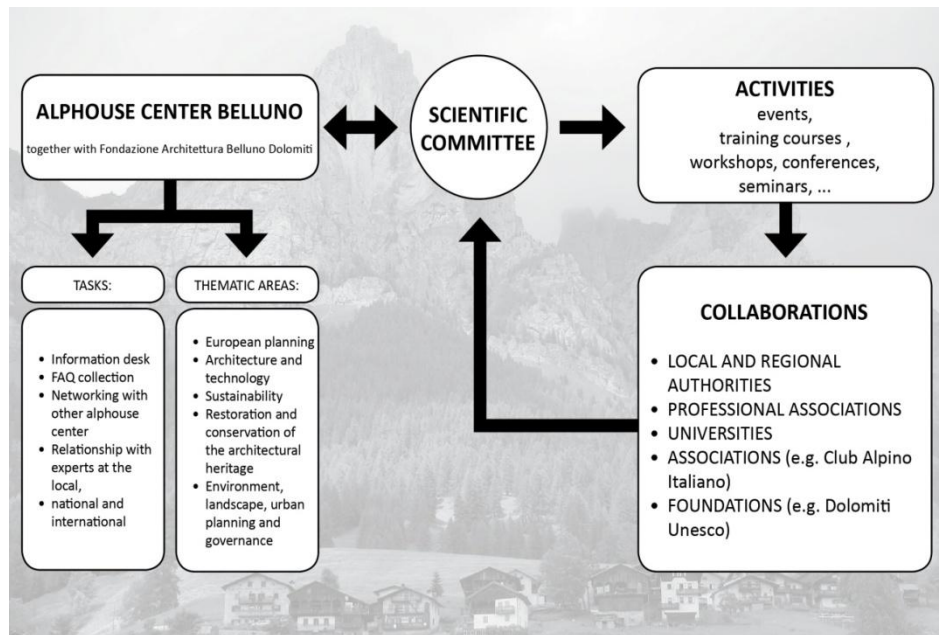
The first aim of the AlpHouse Center of Belluno is to appoint for each one of these issues a contact person with specific expertise with respect to the subject. The work of the contact person will then be supported by the development of a scientific committee made up of experts from different cultural and professional backgrounds. The scientific committee should identify any possible innovative content for every information and training activity in the territory.

As for the main recipients of the actions referring to the AlpHouse Center of Belluno, the preliminary activities have identified some categories of subjects to be preferred. These include firstly local governments, as the subjects that direct, regulate and put forward proposals in the field of construction activities and planning. A second target group is represented by the designers, both as entities that manage the design activities at different scales, and as entities that can collaborate in the program of the AlpHouse Center, through the expression of needs and innovative content. Another target group is then made up of enterprises and artisans, as entities operating in particular in the field of materials and construction techniques. Finally, the AlpHouse Center of Belluno intends to direct its activities towards two additional target groups, not specifically related to the field of building and planning: schools and citizen. The aim in this case, intending the word "culture" in a broader meaning, is to educate and raise awareness about the importance of the traditional built heritage of the area and, above all, of its sustainable development.

As already experienced in the preliminary activities, the purpose of the Center is to interact with the various target groups using a participative approach. Different ways of involving people, such as focus groups, action planning, brainstorming, etcetera, should be individuated from time to time and according to the training objectives of the activities.

Finally, the AlpHouse Center of Belluno aims to develop the following activities:

- the establishment and management of a "permanent information desk", a physical place and a reference point concerning the thematic areas listed above;
- the strengthening of networking with other AlpHouse Centers, in the framework of exchanging and sharing of best practices;
- the creation and implementation of a network of experts in the fields of interest of the AlpHouse Center at local, national and international level;
- the organization of training and information events related to the thematic areas;
- the structuring of a database of best practice related to design, construction, territorial planning, etcetera, available within a website.



*Figure 3- Summary of the organization, structure, objectives, activities and collaborations of the AlpHouse Center of Belluno.*


## 2.3 Summary of the first activities

The AlpHouse Center of Belluno, based on the defined purpose and priority themes and in relation to the target groups that have been identified, has started its activities in May 2015. According to the preliminary activities and the organization foreseen for the AlpHouse Center of Belluno, some training and informative events and activities have been organized. As well as being an important opportunity of sharing knowledge and experience in the territory, these events and activities act as a check on the contents of the Center. Moreover they are an opportunity to gather feedbacks from the users, in order to enhance the future activities of the Center. The aims and thematic areas of the events and activities organized are reported below.


*Table 1- Description of the first activity (21<sup>st</sup> May 2015)*

	Title of the activity: "Culture of living and building in the Alps. Good practices between tradition and innovation in the province of Belluno"
	Type of activity: architectural trip
	Target groups: - professionals in the construction sector
	Objective of the activity: to visit and examine two best practices of new construction and refurbishment of traditional buildings in the alpine context




	<p>Main thematic areas:</p> <ul style="list-style-type: none"> <li>- restoration and conservation of the architectural heritage</li> <li>- sustainability</li> <li>- architecture and technology</li> </ul>
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*Table 2- Description of the second activity (22<sup>nd</sup> May 2015)*


	<p>Title of the activity: "Culture of living and building in the Alps. Conference to present the AlpHouse Center of Belluno"</p>
	<p>Type of activity: convention</p>
	<p>Target groups:</p> <ul style="list-style-type: none"> <li>- professionals in the construction sector</li> <li>- representatives of the construction industry</li> <li>- politicians</li> <li>- citizens</li> </ul>
	<p>Objective of the activity: to present the activity of the AlpHouse Center of Belluno and raise awareness on the integration of sustainability into the planning and construction sector</p>
	<p>Main thematic areas:</p> <ul style="list-style-type: none"> <li>- sustainability</li> <li>- environment, landscape, urban planning and governance.</li> </ul>

*Table 3- Description of the third activity (26<sup>th</sup> June 2015)*

	<p>Title of the activity: "Culture of living and building in the Alps. Good practices between tradition and innovation in the province of Belluno"</p>
	<p>Type of activity: conference and exhibition</p>
	<p>Target groups:</p> <ul style="list-style-type: none"> <li>- professionals in the construction sector</li> <li>- representatives of the construction industry</li> <li>- politicians</li> <li>- citizens</li> </ul>
	<p>Objective of the activity: to present the results of the international design competition for the reconstruction of the alpine hut "Fill. Fanton" in the Dolomites, with a focus on innovative building construction systems and materials in complex environments</p>
	<p>Main thematic areas:</p>

	<ul style="list-style-type: none"> <li>- sustainability</li> <li>- architecture and technology</li> </ul>
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*Table 4- Description of the fourth activity (29<sup>th</sup> June 2015)*

	Title of the activity: "Building refurbishment between tradition and innovation"
	Type of activity: convention
	Target groups: <ul style="list-style-type: none"> <li>- professionals in the construction sector</li> <li>- representatives of the construction industry</li> <li>- citizens</li> </ul>
	Objective of the activity: to inform and raise awareness on the issues of energy efficiency and conservation of traditional architecture
	Main thematic areas: <ul style="list-style-type: none"> <li>- restoration and conservation of the architectural heritage</li> <li>- sustainability</li> <li>- architecture and technology</li> </ul>

Examining the first activities carried out it is possible to underline their character of precursors of the future work of the AlpHouse Center: the activities are characterized by a general rather than specific approach. The most frequently encountered thematic areas have been the sustainability and architecture and technology. In particular sustainability can be considered a field which can involve a wider audience and not only the insiders and which is related to finding a way for the future development of the alpine territory. Moreover, the different thematic areas in most of the case have been treated during meetings open to the public (e.g. convention, exhibition, etc.) and often addressed to a non-specific audience, e.g. citizens. This can be considered a first attempt to create a connection between the AlpHouse Center of Belluno and its territory through participation and to spread a wider idea of the culture of living and building in the Alps. Another feature of some of the activities done regards the idea of knowing and sharing best practices, as claimed in the intents of European cooperation programme and of the AlpHouse Center network.

### 3. Conclusions

The paper have had the aim to present a best practice developed in an alpine area which can be an example to be developed in other areas, in the context of an exchange of experiences. To underline the most relevant findings, the work done in the set-up of the AlpHouse Center, in its organization and in its first activities has observed three main aspects.

First of all, the experience of the AlpHouse Center of Belluno - a permanent center for the culture of living and building in the Alps - reported in this paper, shows the importance of a participative approach and involvement of different target groups and communities in structuring a reference point on the themes of architecture and sustainable planning in the mountain area, in order to set appropriate strategies and solutions to identified needs. This participative approach, also suggested by the Declaration "Population and Culture" (2006), which has been used also in the

preliminary organization of the Center and that aims to be pursued in the future activities, has led to the identification of two elements. Firstly, it identified different persons - governments, professionals, enterprises, schools and citizens - which can be interested in the AlpHouse Center activities and their fields of interest. This allows to structure the training offer and informative offer based on the specific needs that emerged. Secondly, this approach has allowed to identify, with a bottom-up approach, the most significant issues in the field of architecture and planning, as they are perceived from the people involved in the construction and planning sector within the territory of Belluno. The contents of the activities of the AlpHouse Center, in this sense, come from actually detected needs.

From a more general point of view, the creation of the AlpHouse Center of Belluno can be an opportunity for the exchange of experiences and expertise. On one side, this sharing opportunity can be possible between different subjects in the Belluno area in order to develop local awareness, capability and know-how. On the other side, the belonging of the AlpHouse Center to a network of other AlpHouse Centers gives to the Belluno area the possibility to interact with other alpine areas and with other people which live and work in the Alps. This aspects overcomes the idea of isolated mountain area and, on the contrary, supports the idea of the alpine areas as territories of experimentation, as recalled in the introduction of the paper. In this sense the AlpHouse Center of Belluno allows a continuous contact with various knowledge and innovation subjects and the inclusion of the territory of Belluno in the global Alpine context.

Finally, the activities of AlpHouse Center help to ensure that the teaching of a “ante-litteram sustainability” - which is a common aspect to the alpine areas and their traditional buildings and, as have been recalled, a part of an ancient knowledge - can be known, handed down, reinterpreted and then integrated with the new demands for innovation. By trying to combine the collection of this traditional background with the possibility of innovation, the AlpHouse Center can be a reference point for the future sustainable development of the building sector and of the planning activities in the Belluno area. In this sense thus the AlpHouse Center intends to align the experimentations done in an alpine territory with the global objectives of sustainable development suggested by the European Union.

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# New potential indicators for energy matching at neighbourhood level

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## Abstract

The key aspect of the energy matching in the districts is balancing the energy supply from local renewable sources with the energy demand of buildings and other urban infrastructures. The challenge is to simultaneously maximise energy efficiency and minimise peak power demand while maximising local renewable energy supply, including resolving energy storage issues. To avoid sub-optimisation it is important that the wider context is considered in the design and operation of neighbourhood's energy systems throughout its entire life cycle. The purpose of this study was to address this challenge by bringing new metrics to assess how well the local renewable supply meets the local demand in the neighbourhood level. A set of new key performance indicators (KPIs) is proposed for evaluating the energy positivity level of neighbourhoods. These KPIs include yearly on-site energy ratio (OER) and energy mismatch indicators for each energy type (heating, cooling and electricity). The mismatch indicators include annual mismatch ratio (AMRx), maximum hourly surplus (MHSx), maximum hourly deficit (MHDx) and monthly ratio of peak hourly demand to lowest hourly demand (RPLx), where x is replaced by an indicator for the different energy types respectively (h for heating, c for cooling, e for electricity). This is followed by presenting the first results from a number of energy simulations where the indicators are calculated. It can be observed that the threshold or target values for the indicators might be different for different countries. In a southern country it might be easier to meet the low AMR values by increasing local solar energy supply, if the local demand is predominantly caused by electricity driven cooling and domestic hot water. The indicators presented here proved useful in considering the probable configurations for the near future aiming at nearly zero-energy neighbourhoods. An interesting finding is that the on-site energy ratio also reveals the best energy efficiency level of buildings studied.

**Keywords:** Key performance indicators, energy matching, energy positive, neighbourhood

# 1. Introduction

In the near future, energy demand of buildings is expected to decrease. The Energy Performance of Buildings directive (EC, 2010/31) guides to adopting highly efficient nearly zero energy building performance requirements for both new and existing buildings, leading to so-called nearly zero-energy buildings. Lately the focus has been broadening towards zero energy neighbourhoods, or even energy positive neighbourhoods (e.g. Ala-Juusela et al. 2014 and Marigue et al. 2014).

In the longer term, zero energy and energy positive buildings are seen as an active part of cities' energy systems, contributing among others to increased share of renewable energy sources use and intelligent energy management (Kylili and Fokaides, 2015). Additionally, for example a report from a European Large Scale bridging Action (ELSA) Thematic Working Group on ICT for energy efficiency concluded that (Davis, 2009): *"Energy-positive buildings and neighbourhoods are those that generate more power than their needs. They include the management of local energy sources (mainly renewable, e.g. solar, fuel cells, micro-turbines) and the connection to the power grid in order to sell energy if there is excess or, conversely, to buy energy when their own is not sufficient"*. The traditional role of buildings is transforming from energy consumers to small scale energy producers, or so-called prosumers (Picciariello et al. 2015; Rathnayaka et al. 2015). Matching of energy supply and demand on the neighbourhood level is one step in this long term development.

Energy matching aims to balance the energy supply from local renewable sources with the energy demand of a neighbourhood (Pina et al. 2012; Sunliang et al. 2013). This will include maximising energy efficiency and minimising peak power demand, while maximising the local renewable energy supply and the management of energy storage. The energy demand and its potential flexibility (shifting of times of use etc.) can be utilised for energy matching with the available local renewable energy sources, and/or with the energy tariff levels from energy markets (Heimonen et al. 2012). To avoid sub-optimisation it is important that the wider context is considered in the design and energy operation of neighbourhood throughout its entire life cycle. The appropriate time scales and energy components for studying the matching of energy demand and renewable supply can vary.

The research question was to study what are the new energy matching indicator values for different kinds of neighbourhoods located in Helsinki, Finland and Madrid, Spain, and how they can be used to compare the studied neighbourhoods. In this work, neighbourhoods have been defined as a group of buildings, which have a common geographical location and are served by common energy networks. The more detailed boundaries for the concept of neighbourhood depend on the studied case. Energy demand of a neighbourhood includes in this study the energy demand of buildings, but in general, the scope could also include the energy demand of transportation and other urban infrastructures (such as waste and water management, parks, open spaces and public lighting).

## 2. Methodology

### 2.1 KPIs for matching the neighbourhood energy supply and demand

Ala-Juusela et al. (2014 and 2015) have developed a set of key performance indicators (KPIs) for assessing the matching of energy demand and supply of a neighbourhood. In addition to meeting the overall annual energy balance, it is important that different types of energy are taken into account and the timing of the supply and demand of these different types of energy is matched as well as possible.

The KPIs developed to measure the energy positivity level of a neighbourhood (Ala-Juusela et al. 2014 and 2015) include yearly on-site energy ratio (OER) and energy mismatch indicators for each energy type (heating, cooling and electricity). The mismatch indicators include annual mismatch ratio (AMR<sub>x</sub>), maximum hourly surplus (MHS<sub>x</sub>), maximum hourly deficit (MHD<sub>x</sub>) and monthly ratio of peak hourly demand to lowest hourly demand (RPL<sub>x</sub>), where x is replaced by an indicator for the different energy types respectively (h for heating, c for cooling, e for electricity).

The overall balance between annual energy demand and local renewable supply is indicated with the **On-site Energy Ratio (OER)**, which is the ratio of these two:

- Annual energy supply from local renewable sources (all energy types together)
- Annual energy demand (all energy types together).

The short term imbalances are indicated with:

- **Annual Mismatch Ratio (AMR)**, which indicates how much energy needs to be imported into the area for each energy type on average. It is the annual average ratio of these two, for those hours when the local demand exceeds the local renewable supply:
  - hourly difference between demand and local renewable supply (by energy type)
  - hourly demand (by energy type) during that same hour
- **Maximum Hourly Surplus (MHS)**, which is the maximum yearly value of how much the hourly local renewable supply overrides the demand during one single hour (by energy type)
- **Maximum Hourly Deficit (MHD)**, which is the maximum yearly value of how much the hourly local demand overrides the local renewable supply during one single hour (by energy type)
- **Monthly Ratio of Peak hourly demand to Lowest hourly demand (RPL)** indicates the magnitude of the peak power demand, and it is calculated as the ratio of these two (by energy type):
  - The highest value for hourly demand over the month
  - The lowest value of hourly demand over the month (0-values are ignored)

It is worth noticing that  $OER=1$  means zero energy building or neighbourhood and  $OER>1$  means energy positive building or neighbourhood.  $OER<1$  indicates that a building or a neighbourhood requires imported energy, i.e. it represents a typical situation today.

AMR indicator can have values between 0 (meaning perfect match) and 1 (no match at all), i.e. the smaller value AMR has, the better the local renewable supply matches with the demand.

## 2.2 Energy simulations

Altogether, 60 energy simulations were carried out for different combinations of building categories, their technical systems and usage profiles. These will be described in the following sections. Dynamic simulation software IDA-ICE (Equa 2013) was used.

## 2.3 Simulated scenarios

Hourly simulations for demand and renewable supply over one year were conducted. All the different cases were simulated in two different climates: Helsinki, Finland, representing Northern climate (60°10'10" N; 24°56'07" E) and Madrid, Spain, representing Southern climate (40°24'59" N; 3°42'09" W).

### 2.3.1 Buildings

Two broad types of buildings were simulated: a residential single-family building and an office building, both with variable construction technology, users and renewable energy supply (see Table 1 and Table 2).

*Table 1: A summary of the simulated variables for the residential buildings.*

(18) Detached houses in Helsinki / Madrid	1	2	3
<b>Energy class</b>	Normal wooden house	LowE wooden house	Old massive HighE house
<b>User class</b>	4 persons, wake-up late	4 persons, wake-up early	Retired couple
<b>Orientation class</b>	Facing South	Facing East	-

For the residential building, three different types of construction technology were simulated: a wooden house complying with current requirements from the building code, a low-energy wooden house and an old massive house with high energy use. For the simulation of residential buildings, also three types of user profiles were used: a family of four, waking up relatively late, another family of four, but with a habit to wake up early, and a retired couple (Figure 1). These all have different behaviour patterns, affecting the timing of the energy use, and therefore also the possibilities to match the renewable supply with the demand on the right time. The third variable parameter was the orientation of the house, either to South or to East. All different building



technologies, user types and orientations were combined, resulting in total of 18 different configurations (3 construction types x 3 user types x 2 orientations).

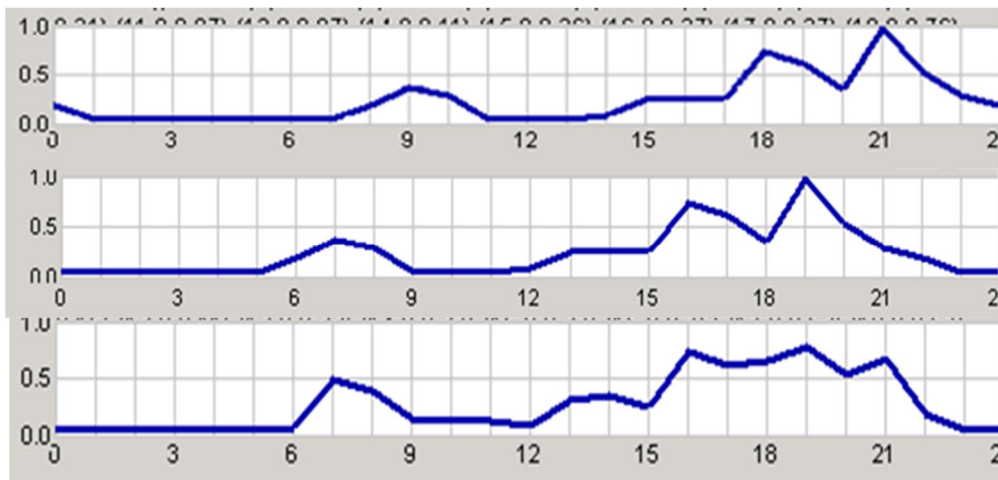


Figure 1: Different daily schedules for electricity use for the three user types.

For the office building, three different types of construction and building technology were simulated: A building with normal insulation level and heat recovery, a low energy office building and an old house with high energy use and no ventilation heat recovery. The second variable parameter was the orientation of the building, either to South or to East. For the simulation of office buildings, also two types of window shading options were used: no shading, or external shading, lights and schedule control. All different building technologies, orientations and window shading options were combined, resulting in total of 12 different configurations for the office building (3 construction types x 2 orientations x 2 window shading options).

Table 2: A summary of the simulated variables for the office buildings.

(12) Offices in Helsinki / Madrid	1	2	3
<b>Energy class</b>	Normal insulation and heat recovery	LowE building	Old High Energy building, no ventilation heat recovery
<b>Orientation class</b>	Facing South	Facing East	-
<b>Window shading</b>	No shading	External shading, lights and schedule control	-

### 2.3.2 Renewable production

Three types of renewable production were simulated: photovoltaic panels, solar thermal collectors and wind power. Three orientations and two tilt angles were simulated for the solar panels and collectors: South 45°; South-East 60° and South-West 60°. The nominal power of the wind turbine

was 5300 W. The simulations for solar yield were conducted for 1 m<sup>2</sup> of panel or collector area, so the size of the solar installation can be varied in the scenarios.

### 2.3.3 New indicators at building level

As a first approach all possible building variations were considered and the new indicators were calculated for each case in two climatic zones: Northern represented by Helsinki and Southern represented by Madrid. In both climates the renewable energy generation was assumed to be solar collectors and PV panels (4 and 2 m<sup>2</sup> respectively for detached houses and 120 and 80 m<sup>2</sup> respectively for office buildings) tilted 45° and facing south. The results are summarised in Figure 2 for Helsinki and in Figure 3 for Madrid.

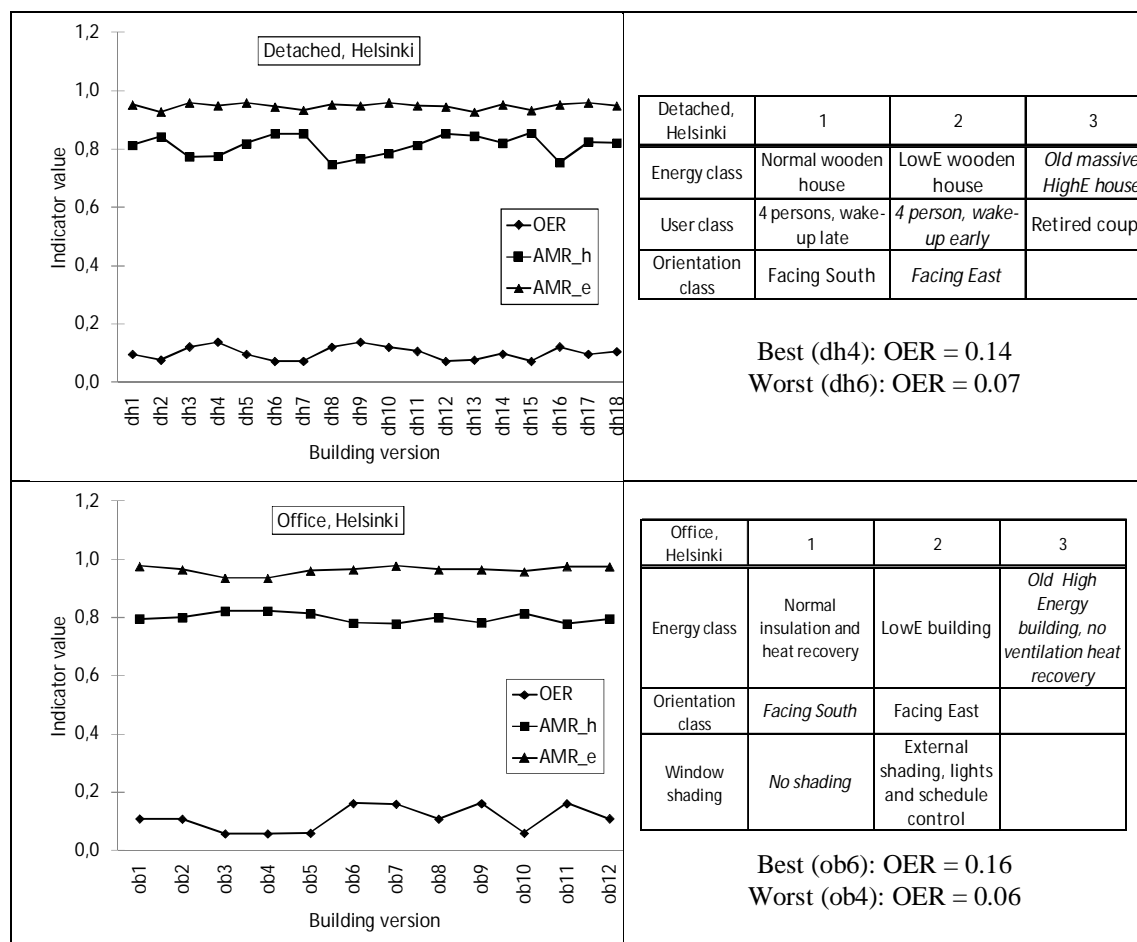


Figure 2: New KPI-indicators for all possible building versions (left) and best and worst building versions (right) in Northern climate (Helsinki).

From the energy consumption point of view, the most energy-efficient detached building version (dh4 in Figure 2) is the one with also the highest OER-indicator, i.e. the low energy wooden house, facing south and occupied by a retired couple. This result is marked with bolded font in the table up-right in Figure 2. The other extreme, the worst solution from energy point of view (dh6 in Figure 2) is the one with also the lowest OER-indicator, i.e. old massive high energy house, facing east and occupied by 4 people rising early in the morning. This result is marked

with italic font in the table up-right in Figure 2. The range between extreme values of OER indicators imply that the worst solution will use double the amount of energy compared with the best solution.

Respective analysis for office building solutions show that the most energy efficient office building version (ob6 in Figure 2) is the one with also the highest OER-indicator, i.e. the low energy building, facing east and equipped with external shading and having lighting with schedule control. This result is marked with bolded font in the table low-right in Figure 2. The other extreme, the worst solution from energy point of view (ob4 in Figure 2) is the one with also the lowest OER-indicator, i.e. old high energy building without ventilation heat recovery, facing south and having no shading. This result is marked with italic font in the table low-right in Figure 2. The range between extreme values of OER indicators imply that the worst solution will use approx. 2.5 the amount of energy compared with the best solution.

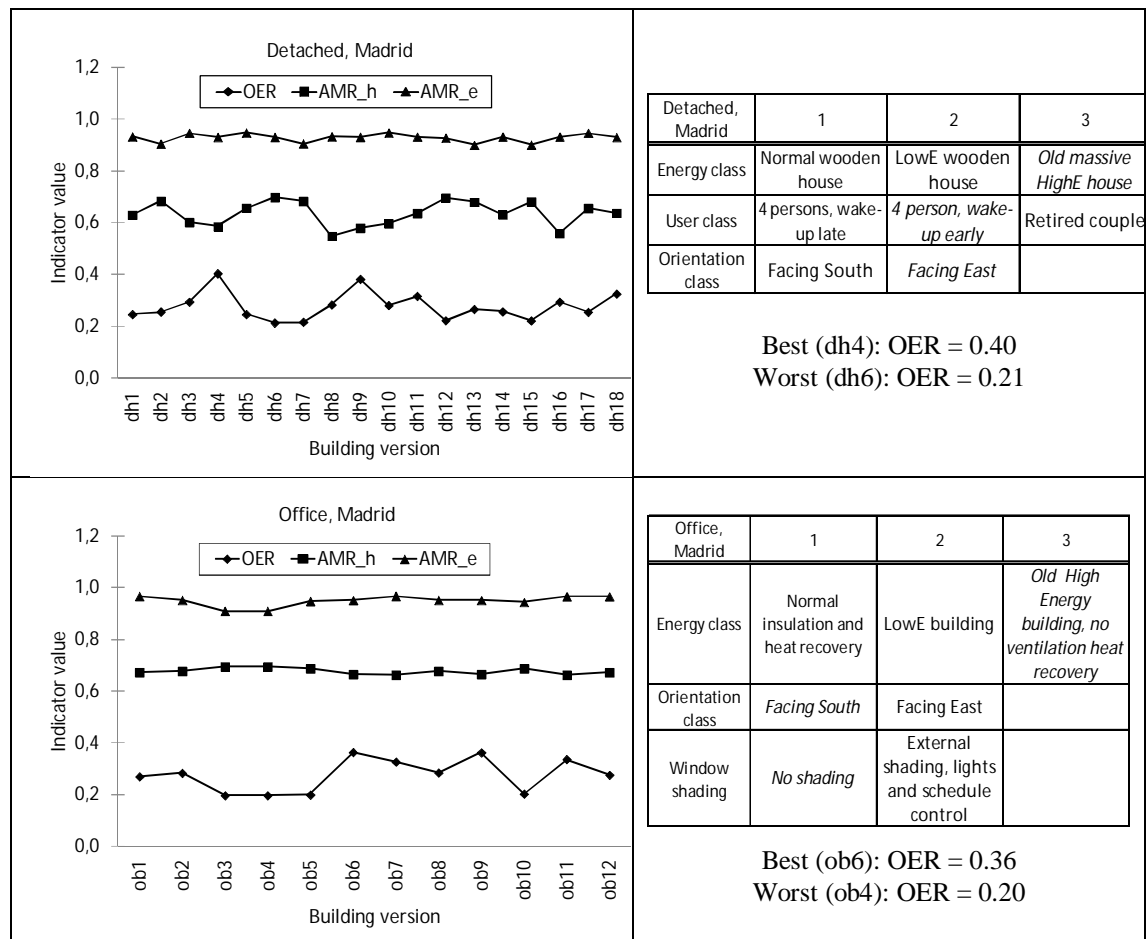


Figure 3: New KPI-indicators for all possible building versions (left) and best and worst building versions (right) in southern climate (Madrid).

An analysis of the exactly respective building versions simulated in Southern climate is summarized in Figure 3. It is easy to notice that it allows for similar conclusions as above. The same building versions were identified as the best and the worst solutions, both for detached houses and offices, respectively. However, it is worth noticing that the values of OER indicator

in Southern climate are considerably higher compared with the values in Northern climate. This is obviously telling that buildings with identical construction located in mild climate will consume less energy, and considerably more renewable energy is available for use there, compared with Northern climate, see Figure 3.

### 3. Simulated energy matching indicators at neighbourhood level

The simulated buildings and renewable production elements can be combined into different neighbourhoods to study which combinations would lead to energy positivity on the neighbourhood level. The buildings selected for the following analysis include: ob6 (the most effective office), ob12 (standard office), dh4 (the most effective detached house), dh14 (standard detached house), and a few other detached houses with different energy classes, user classes and orientations (dh9, dh10, dh11). These buildings were preselected from among all carried simulations described in previous section. All of the preselected buildings are identified in Table 3.

*Table 3: Definition of the detached houses and the office buildings used in the neighbourhood analysis. (For numbering of different classes, see Table 1 and Table 2)*

Detached house	dh4	dh9	dh10	dh11	dh14	Office	ob6	ob12
Energy class	2	2	2	1	1	Energy class	2	1
User class	3	3	2	3	1	Orientation class	2	1
Orientation class	1	2	2	2	1	Shading type	2	1

It was assumed that the neighbourhood would be located in Southern climate (Madrid) and would consist of 10 buildings, including at least 1 office. The amount of other buildings could vary.

The following exercise was carried out to study how to arrive from a solution that would be a standard today to an energy positive neighbourhood. The steps are represented by the following cases: (1) standard today, (2) low energy, (3) balanced mixture, (4) enhanced mixture and (5) energy positive neighbourhood. The cases are defined with further detail in Table 4.

This means that the neighbourhood in Case 1 consists of 8 detached houses (each type dh4, with 4 m<sup>2</sup> of solar collectors and 2 m<sup>2</sup> of PV panels on each building) and 2 offices (each type ob12, with 120 m<sup>2</sup> of solar collectors and 80 m<sup>2</sup> of PV panels on each building). Neighbourhood in Case 2 consists of 9 detached houses (type dh4 each) and one office building (type ob6), etc.

For each case, the energy consumptions, renewable generations and corresponding KPIs were calculated not only for each individual building but also for the group of buildings and for the entire neighbourhood level. The results are summarized in Table 5.

Table 4: Cases 1 – 5 in Madrid climate.

<b>Case 1</b>	dh4	dh9	dh10	dh11	<b>dh14</b>	ob6	<b>ob12</b>
Amount of buildings					8		2
Solar thermal, m <sup>2</sup>					4		120
Photovoltaic, m <sup>2</sup>					2		80
<b>Case 2</b>	<b>dh4</b>	dh9	dh10	dh11	dh14	<b>ob6</b>	ob12
Amount of buildings	9					1	
Solar thermal, m <sup>2</sup>	4					120	
Photovoltaic, m <sup>2</sup>	2					80	
<b>Case 3</b>	<b>dh4</b>	<b>dh9</b>	<b>dh10</b>	<b>dh11</b>	<b>dh14</b>	<b>ob6</b>	<b>ob12</b>
Amount of buildings	2	2	1	1	2	1	1
Solar thermal, m <sup>2</sup>	4	4	4	4	4	120	120
Photovoltaic, m <sup>2</sup>	2	2	2	2	2	80	80
<b>Case 4</b>	<b>dh4</b>	<b>dh9</b>	<b>dh10</b>	<b>dh11</b>	<b>dh14</b>	<b>ob6</b>	<b>ob12</b>
Amount of buildings	2	2	1	1	2	1	1
Solar thermal, m <sup>2</sup>	8	8	8	8	8	120	120
Photovoltaic, m <sup>2</sup>	8	8	8	8	8	240	240
<b>Case 5</b>	<b>dh4</b>	dh9	<b>dh10</b>	dh11	<b>dh14</b>	<b>ob6</b>	ob12
Amount of buildings	7		1		1	1	
Solar thermal, m <sup>2</sup>	12		12		12	240	
Photovoltaic, m <sup>2</sup>	12		12		12	320	

The target of the exercise was to obtain the energy positive neighbourhood (OER>1). Therefore the change from Case 4 to Case 5 essentially meant to sufficiently increase the local generation, i.e. the area of solar panels.

The Case 5 was also calculated in Northern climate and the results are included in the last column in Table 5. The comparison with Case 5 in Madrid climate shows that the neighbourhood that is clearly energy positive in Southern climate is far from being positive in Northern climate (compare OER values 1.13 vs 0.42). To achieve this position, considerably more renewable generation would be required for heating function.

Table 5: Results of analysis for Cases 1-5 in Madrid climate, including Case 5 also in Helsinki climate.

	Case 1	Case 2	Case 3	Case 4	Case 5	Case 5 (Helsinki)
<b>Detached houses</b>						
Amount of buildings	8	9	8	8	9	9
Heating, kWh/m2	40.6	24.5	31.6	31.6	27.2	69.1
Electricity, kWh/m2	41.4	27.6	33.5	33.5	30.9	27.1
Total, kWh/m2	82.1	52.2	65.0	65.0	58.0	96.2
OER	0.26	0.40	0.32	0.71	1.19	0.43
AMR_h	0.63	0.59	0.60	0.58	0.56	0.75
AMR_e	0.93	0.93	0.93	0.78	0.73	0.81
<b>Offices</b>						
Amount of buildings	2	1	2	2	1	1
Heating, kWh/m2	28.7	12.6	20.7	20.7	12.6	63.1
Electricity, kWh/m2	103.6	87.6	95.6	95.6	87.6	71.1
Total, kWh/m2	132.4	100.3	116.3	116.3	100.3	134.2
OER	0.28	0.36	0.31	0.39	0.82	0.36
AMR_h	0.67	0.67	0.67	0.67	0.66	0.78
AMR_e	0.97	0.95	0.96	0.89	0.84	0.89
<b>Neighbourhood</b>						
Amount of buildings	10	10	10	10	10	10
OER	0.26	0.40	0.32	0.61	<b>1.13</b>	0.42
AMR_h	0.64	0.59	0.62	0.60	0.57	0.75
AMR_e	0.94	0.93	0.94	0.80	0.74	0.82

## 4. Discussion and conclusions

The exercise presented in this paper was aimed to imitate the work architects presumably do today in their daily practice without having easy tools to assist them in considering energy aspects of their designs. While tools to simulate energy consumption of single buildings are available, they also usually require a considerable degree of expertise not only to set up and run them but also to interpret the results. The new KPIs for energy matching of buildings and neighbourhoods are aimed to help in this context. The studied KPIs help to assess the energy positivity level of neighbourhoods, meaning that how well the local renewable supply meets the local demand at the neighbourhood level. The KPIs include yearly on-site energy ratio (OER) and energy mismatch indicators for each energy type (heating, cooling and electricity). The mismatch indicators include annual mismatch ratio (AMRx), maximum hourly surplus (MHSx), maximum hourly deficit

(MHD<sub>x</sub>) and monthly ratio of peak hourly demand to lowest hourly demand (RPL<sub>x</sub>), where x is replaced by an indicator for the different energy types respectively.

The simulation results indicate that it is relatively easy to draw conclusions based on simple values of OERs and AMRs to guide architect in making educated choices in an early design stage that would be difficult or impossible to change in a later stage of the process. Achieving zero energy building or neighbourhood requires that OER=1, or higher for energy positive buildings and neighbourhoods. AMR indicator shows the level of energy matching (how well energy demand and supply are corresponding), with AMR values ranging from 0 for a perfect energy match to 1 for no match at all. This information could also be used already in the land use planning when aiming to energy efficient, zero energy or energy positive neighbourhoods.

Because the proposed KPIs are new, further experimentation is needed to gain confidence before it will be safe to propose any target values for these new KPIs to be used as reference for architects in making designs. Experiment presented in this paper showed that such target values will certainly have to be different in different climates.

From the methodological point of view, it is advisable to run large number of simulations varying a number of design parameters and draw conclusions using KPIs. Already today using KPIs in a manual manner, as presented in this paper, will improve the design of neighbourhoods. In the future the process could be further developed including optimisation function. Thereafter, it could be made even easier and faster by making the whole process automatic.

In the development of the indicators presented here only the probable configurations for the near future were considered, which will be nearly zero-energy neighbourhoods with relatively modest excess energy supply. Further ahead into the future, there might exist neighbourhoods that aim to make a financial profit by producing much more energy than the local demand, and storing some of the energy to be sold when the demand on national market is high and the price for the energy is at its peak. These kinds of future scenarios will require a rethinking of the indicators.

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# **Integrating sustainability into real estate and construction business development.**

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## **Abstract**

Ramboll Green Market study (GMS) on 2014 was the fourth survey since 2008. The purpose of the study was to find out how sustainability is integrated into real estate and construction business in the Nordic countries. The GMS contains questions about management, operation and development for tenants, property managers, owners, developers, construction industry, designers and municipalities. It provides a view of the drivers, emerging topics, challenges and opportunities towards sustainability.

Assumptions were made before the GMS study based on the market situation and previous studies: the role of the user as the customer has been enhanced, tighter economic situation has reflected to the need to find cost savings, new technical systems are emerging and “green building is becoming the standard.” It was assumed that new technologies and accounting sustainability requires more communication.

Based on GMS study the development has resulted in more efficient use of resources, increased significance of green buildings and co-operation between stakeholders. 71% of respondents saw the environmental values as a part of the corporate responsibility strategy. The respondents clearly indicated that green premises will become considerably more common in 5 years. Tenants seemed to be well aware of the green premises positive impacts and are willing to pay slightly (< 3 %) more of the green premises.

According to the study, the industry in Nordic countries has strong trust in integrated solar energy production. In area planning global warming, scarcity of natural resources and primary energy consumption were ranked as the most important sustainability topics. Great majority (93 %) do believe life cycle contract projects to become more common in the near future. There is also need for whole building life cycle consideration that require holistic data collection and sharing with building information modelling (BIM). The greatest possibilities to influence sustainability integration were seen in participation in EU decision-making and through education.

85% of the GMS respondents were aware of environmental impacts monitoring. Monitored indicators are most commonly communicated to the stakeholders within the annual report.

Annual report may not be active and engaging communication for integrating sustainability, but a place to show what is done.

**Keywords:** sustainability, real-estate, construction, communication, measurement

# **1. Introduction**

In 2014 spring it seemed that the Nordic countries real-estate industry had found the key environmental aspects. Heads were turned towards actions in measurement, communication and constant improvement operations. The economic situation had tightened the monitoring of building efficiency and environmental certification helped to find the customers in the tight competition of tenants. The environmental monitoring tools nationally and globally such as LEED (Leadership in Energy and Environmental Design) and BREEAM (BRE Environmental Assessment Method) for real estate industry had revealed the front runners that wanted to show their superiority. Independent bodies showed their environmental aspects with public administrated example buildings. These were assumptions and the aim was to find out what was actually happening. This paper was written to find out if the Green Market Study 2014 (GMS) and statistics show the same results as assumed.

## **2. Ramboll Green Market study (GMS) 2014 background**

### **2.1 Purpose of the study**

The purpose of the study was to find out how sustainability is integrated into real estate and construction business in the Nordic countries. New sustainable innovations were sourced. It was believed that new business models needed to be developed to support sustainability and data management will be needed. It was assumed that because of the economic situation, the increased competition of tenants will emphasise the user wishes and find new cost savings from e.g. new technical systems. Also, it was believed that “green building is becoming the standard.” All stakeholders need to adjust to the new situation and communicate with each other’s. The study was done to find out what is now developing fastest in the markets.

### **2.2 GMS Survey questions and respondents**

GMS 2014 is the fourth insight of real estate business trends and development related to sustainability and green building in Nordic countries since 2008. Themes included real estate and construction industry trends yesterday and today, real estate data monitoring and utilization and green values. Also respondents’ views on the future of the real estate and construction industry were inquired. GMS 2014 aimed to focus more on the views of tenants. The topics of GMS 2014 were selected in co-operation with Ramboll specialists.

The trends contained questions about important aspects and reasons influencing to environmental awareness and possible barriers for not doing so. To found out the trends, same questions are asked in every time GMS since 2008 and also future aspects are included. Data monitoring questions were detailed to found out what exactly is measured, how it is communicated and what influences measurement has. Additionally survey contained questions about tools that are used

for real estate sustainability performance evaluation. Many questions were related to sustainable values and new innovations on the field were discussed.

The data for GMS 2014 was collected with an on-line survey within real estate and building industry professionals, tenants and industry peers. Link was available on the web page and send to real estate operators. The survey was conducted in August 2014. The survey had a total of 177 respondents. Approximately 45% of respondents work in the public sector and 55% in the private sector. Respondents gave also answer for their respondent group based on their position in organisation with company management (19%), operative management (33%), expert or consultant (47%) and other (1%) groups.

Most of the answers gained (98 %) were from Finnish company operators. The answers were divided based on real estate sector operator groups. Answers divided quite evenly for all the groups shown below.

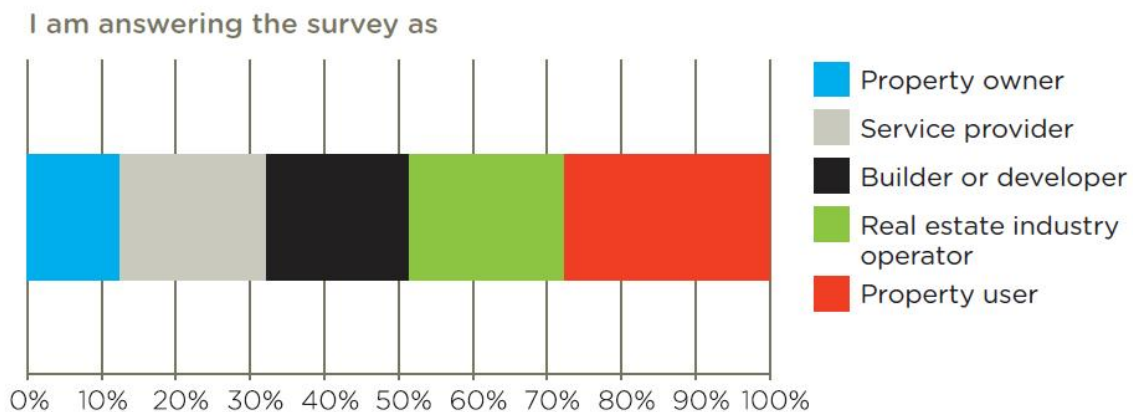


Figure 1: Green Market Study respondent groups in Ramboll Green Market Study 2014

## 2.3 The accuracy of the background assumptions

As pointed out earlier, it was assumed that because of the economic situation, the increased competition of tenants will emphasise the user wishes and find new cost savings from e.g. new technical systems. Also, it was believed that “green building is becoming the standard.”

The number of certified buildings is increasing in the Nordic countries. According to article by Ryan Zizzo (2013) “the popularity of green building rating systems in general and LEED in particular has grown quickly over the past decade” (pp.1). FIGBC (Green building council Finland) that keeps combined records on the certifications with LEED and BREEAM announces that in in November 2015 the amount has reached more than 120 LEED and BREEAM certified buildings in Finland (Finnish green building council, 2015). According to Swedish Green building council there are **632** Swedish buildings certified with Swedish certifying system “Miljöbyggnad”

and **266** buildings certified with GreenBuilding (Swedish BREEAM) (Swedish green building council, 2015). The amount of certified buildings is hence bigger in Sweden currently.

Both Sweden and Norway have integrated the BREEAM for their own countries. According to Norway Green building council the amount of BREEAM certified or registered buildings in Norway is 40 (Norwegian green building council, 2015). Green Building Council Denmark has established a Danish certification within sustainability: DGNB Denmark. According to the page there are currently 17 certified buildings (Denmark green building council, 2015).

On 2012 the GMS survey results showed that people are more familiar with the tools to improve sustainability than 2010. This can be seen from the number of “I do not know” - answers that were greatly diminished especially for BREEAM, ISO standards, Green Office (tool from WWF), Green Lease (contract for green buildings) and carbon footprint calculations (Pöyry Kaupunki ja liikenne liiketoimintaryhmän julkaisu, 2010). Above written is the background for the assumption “green building is becoming the standard.”

Good economic indicators are the share prices. According to Nordic Statistical Yearbook 2014 (Klaus Munch Haagensen, 2014) *from 2003 to the spring of 2007, share prices increased markedly in all Nordic countries – and definitely more than in the remaining West European countries. The increase happened after a considerable decrease in especially technological shares from 2000 to 2003. From the end of 2007, Nordic shares have decreased drastically as a result of the general crisis in the world economy. Despite a turning point in 2009 the share prices have not yet fully recovered.* The above mentioned and graph below illustrates well how the assumption for increased competition of tenants in the more competitive markets.

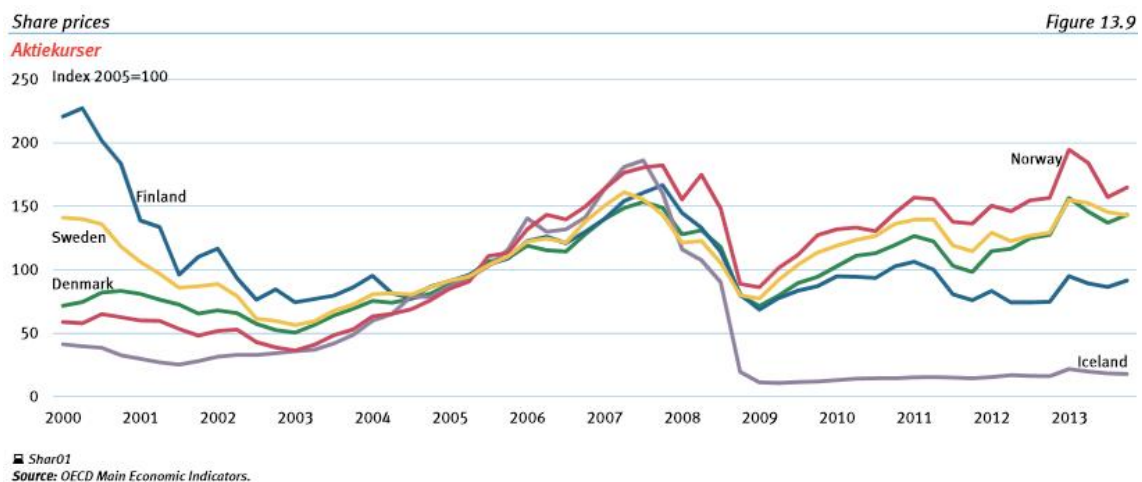


Figure 2: Nordic Statistical Yearbook 2014, OECD main economic indicators, Share prices 2014(Klaus Munch Haagensen, 2014)

### 3. Ramboll Green Market Study (GMS) driving forces towards sustainability 2008, 2010, 2012 and 2014

In 2008 the GMS results showed that respondents expected environmental issues to be dealt out of responsibility (Pöyry building services Oy:n julkaisu, 2008). In 2010 GMS results showed that respondents expected market opportunities and business development from Sustainability consideration. The front runners of the industry were clearly in the construction field (Pöyryn Kaupunki ja liikenne liiketoimintaryhmän julkaisu, 2010). Since then the will of the organisation key players and legislation have increased on the similar level as these earlier more recognized drivers which indicates that the market is changing. Sustainability is now driven from all the reasons mentioned above (Pöyry urban business group, Real estate consulting and design, 2012).

On 2014 the influence of regulation and legislation as an environmental driver in the business has become more evident. Regulation and legislation has become considerably stricter after 2010. At the same time, environmental values are not seen any more as a strong opportunity for strengthening company brand and image. Therefore the forecast of GMS 2010 has realized in part as regulation and legislation guide the environmental decisions in the real estate and construction industry. However, this far energy costs increase has not impacted as significantly as it was believed and seen in the figure below.

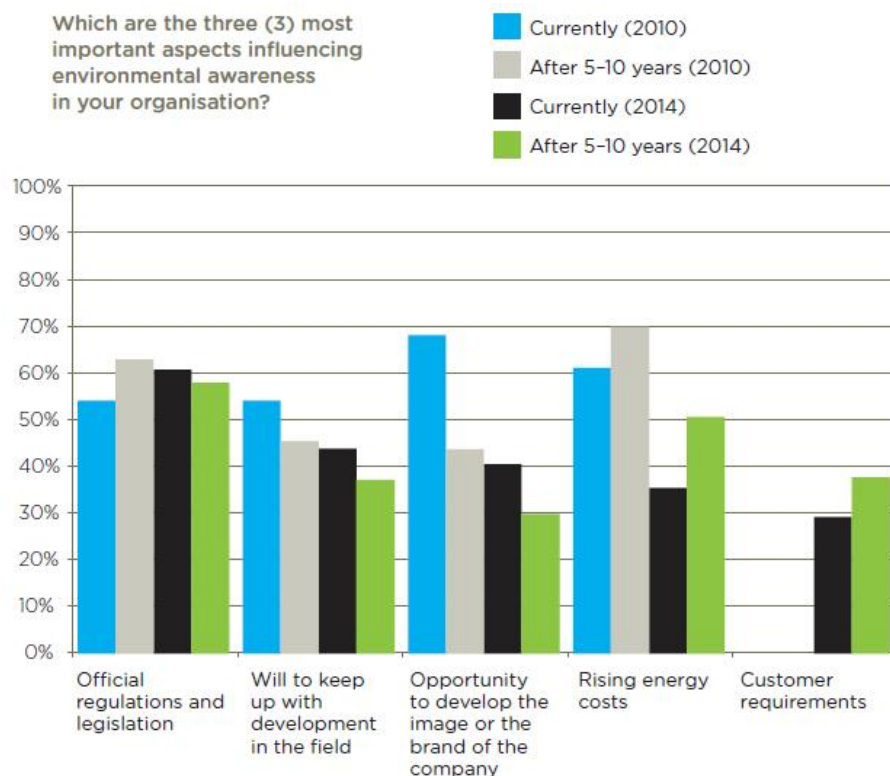


Figure 3: Green Market Study environmental aspect drivers according to Ramboll Green Market Study 2014

According to GMS 2014, half of the respondents believe that in the future the cost of energy will become one of the most significant factors in coming 5–10 years with the legislation. New driver

was added to the survey 2014 “customer requirement”. It is shown that it is believed to become more important in future with the factor “keep up with the development”. This indicates that the “green is becoming the new standard level” and new innovations are needed for the emerging front runners.

## **4. Results**

According to GMS 2014 premises are selected based on the location, cost, modification potential and access to public transportation network. Premises are built based on location, energy and water use efficiency, cost, modification potential and access to public transport network. According to GMS 2014 real estate environmental certification has clearly no influence in premise selection decision (3 %), but 30 % of the owners and construction professionals answered that environmental certification effects to the decision making (Ramboll Finland publications, 2014). However, tenants seem to be very well aware of the green premises positive impacts and are willing to pay slightly (less than 3 %) more of the green premises.

85% of the respondents are aware of environmental impacts monitoring. 18% of respondents say that they do not know if monitoring key environmental indicators influences decision-making in the company. The figure below illustrates the environmental indicators according to GMS 2014 that are monitored, should be monitored and are estimated to be monitored in coming 5 – 10 years.

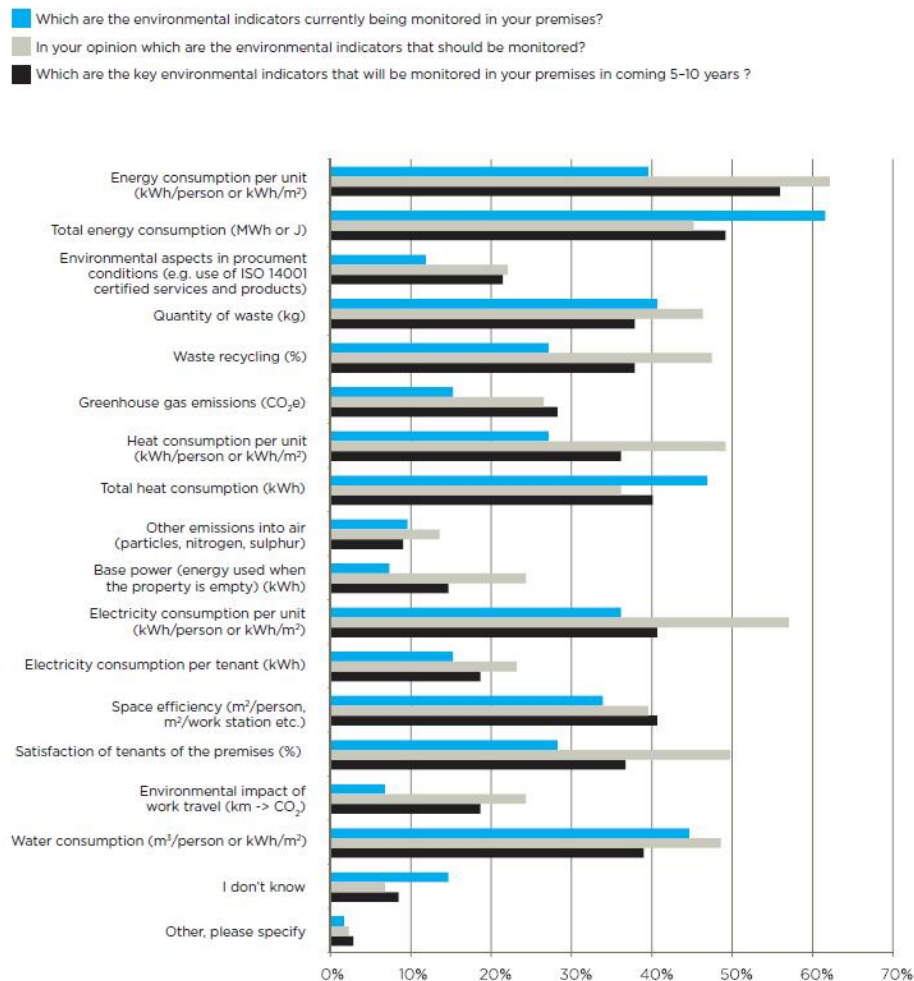


Figure 4: Green Market Study environmental indicator monitoring according to Ramboll Green Market Study 2014

When it was asked what environmental indicators are followed, companies are extensively monitoring energy and water consumption in total and also at tenant level. Fourth monitored key variable is the amount of waste, but recycling rate is left ninth in order of priority. Respondents believe that the trend proceeds towards unit-based monitoring (kWh/m<sup>2</sup>/person/product) in energy consumption, which would improve the use of data in facility and operations management. When asked what should be monitored, tenant satisfaction and waste recycling rate are also stated alongside the traditional indicators. (Ramboll Finland publications, 2014)

71% of respondents saw the environmental values as a part of the corporate responsibility strategy. The reason for adding values to strategy is because of legislation, keeping up with the development and company image. 30% of the respondents are members of national Green Building Councils and can therefore be considered part of the front runners. Environmental indicators are most commonly communicated to the stakeholders within the annual report, but issues are also considered strongly in procurement documents, in training and tenant instructions, that indicate true commitment to the strategic values. The next figure illustrates the different stakeholder's communication methods. (Ramboll Finland publications, 2014)



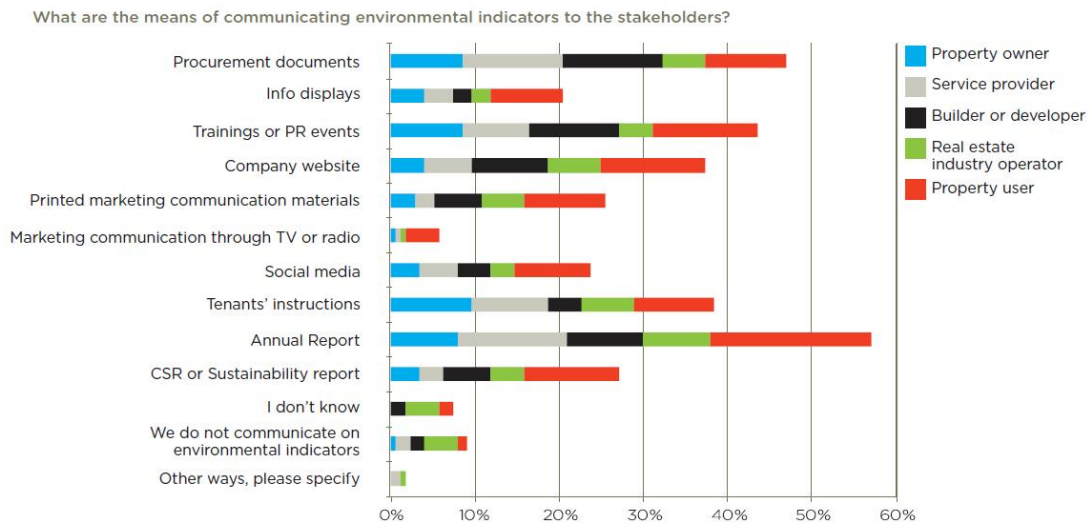


Figure 5: Green Market Study environmental indicator communication according to Ramboll Green Market Study 2014

According to GMS 2014 communication of environmental key indicators is integrated to the instructions of space use. Most commonly instructed are waste recycling and efficient use of energy and water. Tenants are environmentally aware and need more information. The environmental certification systems, standards and tools are well known (LEED and BREEAM among 70 %). The best known and most used green tools are the Nordic Ecolabel, passive house standard, carbon footprint calculations and ISO 14000 environmental management series standards. All respondent groups clearly indicated that green premises will become considerably more common in 5 years. User group estimation can be seen from figure below. (Ramboll Finland publications, 2014)

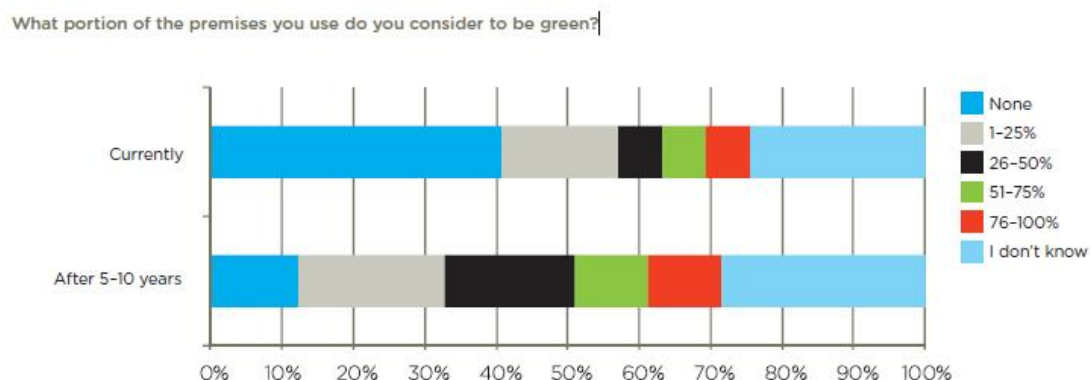


Figure 6: Green Market Study portion of green premises according to Ramboll Green Market Study 2014

Great majority of the respondents (80%) believed that Nordic countries will use more integrated solar energy applications in windows, walls and other building materials. Also it was believed that building information modelling (BIM) (60 %), the zero net energy technologies (57%) and versatility and adaptability of premises e.g. possibility for separate daytime and evening uses will increase (53%). There is also need for whole building life cycle calculation consideration (47 %) and spatial data use (48 %) that accelerates the need for more holistic data collection and sharing with building information modelling (BIM). In project planning global warming, scarcity of natural resources and primary energy consumption were ranked as the most important topics. Great majority (93 %) do believe life cycle contract projects to become more common in the near future. The greatest possibilities to influence were seen in participation (64%) in EU decision-making and through education (64%). (Ramboll Finland publications, 2014)

## 5. Discussion

Before the study it was assumed that the role of the user as the customer has been enhanced, tighter economic situation has reflected to the need to find cost savings, new technical systems are emerging and “green building is becoming the standard.”

According to results the premises are selected based on the location, cost, modification potential and access to public transportation network and environmental certification has no influence in premise selection decision. However, tenants seem to be very well aware of the green premises positive impacts and are willing to pay slightly (less than 3 %) more of the green premises.

One of the most important environmental indicator is energy efficiency (as shown in Figure 4). Regulation and legislation has tightened especially to control building energy efficiency which has resulted in less variation in the energy efficiency of new buildings. On the contrary the energy price has not reached such a level that it would increase the attractiveness of especially energy efficient building that has the environmental certification. At the same time, environmental values are not seen any more as a strong opportunity for strengthening company brand and image. This is perhaps, because more companies are considered to be green?

According to GRESB (global real estate Sustainability benchmark) the overall GRESB scores demonstrate a clear and upward trend in the sustainability performance of property companies and funds since 2013. On 2014 over 93 % have a long-term vision (up from 85 % in 2012) with nearly as many (80 %) also communicating more detailed short-term objectives. Importantly, on 2014 over 80 % involve their senior management board in the reviewing and monitoring of sustainability processes, as compared to 70 % in 2012. On 2015 over 94% of GRESB participants have a senior decision-maker dedicated to sustainability, most commonly a member of the senior management team (49% in 2015 from 42% in 2014). (GRESB, 2014) (GRESB, 2015)

In GMS 2014 environmental indicators are most commonly communicated to the stakeholders within the annual report, but issues are also considered strongly in procurement documents, in

training and tenant instructions, that indicate true commitment to the strategic values. Formal annual report is perhaps not sufficiently active and engaging communication for integrating sustainability, but there the sustainability benchmark numbers are shown comprehensively for the year and compared to the historic data. Social media (24 %) and screens or displays on wall (20 %) are not very actively used although people seem to be spending more and more time with displays. Maybe this is why tenants seem to be lacking information especially on energy efficiency (73 %). It should be kept in mind that 94% of all respondents estimate that their own actions can influence on the energy consumption and costs of their premises. Efficient communication tools for real estate sector might be a true success story for someone as the study was partly set up to develop a business model to support sustainability and data management.

## 6. Conclusions

The purpose of the study was to find out how sustainability is integrated into real estate and construction business in the Nordic countries. It was revealed that the real estate industry sustainability in Nordic countries is driven mainly by legislation and green buildings are becoming standard buildings. As stated in the paper, the number of certified green buildings has increased and people are more aware of the green building benefits. Cost, location and modification potential increase most the real estate attractiveness. Tenants are very well aware of the green premises positive impacts and are willing to pay slightly more (< 3%) of recognized green premises.

As it was stated in the paper, the green building is becoming the new standard. Front runners have to show their commitment with new ways such as using the new clean technology solutions. It was revealed in the GMS that the great majority of the respondents (80%) believed that Nordic countries will use more integrated solar energy applications in windows, walls and other building materials. Also it was believed that building information modelling (BIM) (60 %) and the zero net energy technologies (57%) will increase in future.

The most important environmental indicator of the premise sustainability is energy efficiency. The energy efficiency level in Nordic countries new buildings is high and driven by tight legislation. Energy price has not reached such a level that it would increase the attractiveness of especially energy efficient building. However, sustainability performance of property companies and funds is increasing. That is seen also from GRESB (global real estate Sustainability benchmark) results recently. The GMS respondents believe that the trend proceeds towards unit-based monitoring (kWh/m<sup>2</sup>/person/product) in energy consumption, which would improve the use of data in facility and operations management. Sustainability performance should be shown to the customers with better communication and new innovations will be needed.

The role of the tenant as a property user and customer will most certainly emphasize. According to the GMS study better communication about the sustainability aspects is needed to the stakeholders. As an example tenants see that their own actions can influence on the energy costs

of their premises and need up to date information on their environmental impacts in the building. Tenants would like to share information more about their satisfaction for premises and know actual waste recycling rate. Waste recycling is the most commonly instructed as key indicator alongside efficient water and energy consumption.

New communication ways are needed to improve the messaging. As an example social media or displays on the premises are still used less than expected. New economic situation is also driving the versatility and adaptability of premises e.g. for separate daytime and evening uses (53 % expects to increase) that will need better communication especially between the space users.

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# **A Strategic Tri-Level Relational Model for Building Capabilities and Effective Governance of Complex Adaptive Systems: The English Housing Perspective**

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## **Abstract**

This paper presents a conceptual strategic engagement model which underpins multi-level interventions required for decision-making – especially those governing sustainable transformations. Using the case study of the English housing system, it highlights the importance of integrating complex adaptive systems along with the socio-technical systems theoretical underpinnings, and analyses the strategic interventions needed for populating emerging strategic capabilities (with associated multi-level emerging strategic component-elements). In this context, the discussion includes a conceptual model: Strategic tri-level relational interventions for delivering energy efficiency and sustainability (STRIDES) which makes an innovative contribution to the evidence base for securing successful sustainable transformations.

This research engages the research lens of transdisciplinarity using an explicit mixed methods design to maximise engagement and participation approaches. This includes an online survey, Delphi study and focus group (to embrace multi-dimensional sustainability). The online survey was used to identify latent constructs based on correlated commonly agreed perspectives, which helped to provide multi-framing representations of the domains of housing providers, occupiers and regulators. The Delphi study focused on securing strategic interventions in the existing English housing system, in terms of both the strategic capabilities required for effective governance of these interventions and the strategic outcomes of these interventions. The focus group was used to secure in-depth understanding of the STRIDES model, cognisant of it being ‘fit for purpose’ within the tri-level arrangement.

Research findings highlight the need to strengthen strategic capabilities that draws on systems-thinking – especially for the implications of specificity (within multi-dimensional complex contexts); and the alignment of decision-making strategies which embrace multi-dimensional perspectives and multi-level governance – as these can often constrain systemic responses to

change. The STRIDES model presents a series of sustainable transformational activities in a cogent form through which strategies for energy efficiency and sustainability in societal systems can be effectively leveraged.

**Keywords:** sustainability, transformation, capabilities, systems, governance

## 1. Introduction

Sustainable transformation is rapidly gaining concerns in both academic and organisational domains. It arose from the notion that current decision-making and governance arrangements for transformation do not support those seeking broader and systemic change (O'Brien, 2012). Having recognised the significance of decision-making, a number of studies have provided several insights informing what comprehends in sustainable transformation. Accordingly effective decision-making and governance of sustainable transformation require systemic transformations in fundamentals drawing on transformations in values and beliefs, behaviour patterns, and governing practices. Further, multi-dimensional [demographic, technological, economic, social, cultural, institutional, informational and ideological] sustainability is also needed to be interlinked in order to incorporate coevolution of core concepts of sustainable development in the transformation process (see Patterson *et al.*, 2015).

Despite these advances in the academic domain, holistic understanding of dynamic relationships, mechanisms, processes and conditions essential for sustainable transformations are not clearly established, including its ability to link to decision-making (Willows and Connell, 2003). A major issue is that the existing evidence on decision-making for sustainable transformations is heavily biased towards increasing mitigating capacities to decarbonise including rationalist and linear approach in order to address the “specific risks” identified as a possible solution (Bassett and Fogelman, 2013). As a result, several mitigating interventions have been promoted and implemented by energy-intensive sectors, but it remains unclear how to invest in adaptive capacities that are essential to manage the “generic, complex risks” and building specific capacities<sup>1</sup> identified as crucial to deal with the challenges of decision-making for sustainable transformation (Karpouzoglou *et al.*, 2016).

Within the field of sustainable transformations, adopting systemic approaches and better integrating framing in order to advance collaborative response has recently been identified as a key challenge (Gaziulusoy and Brezet, 2015). However, greater consideration is also needs to be paid to the complexity and integration of dynamic relationships of different perspectives and levels of the whole system (Gaziulusoy, 2015; Spangenberg *et al.*, 2010). This is because the real-world transformation cannot follow a rationalist and linear approach evolved from the science of

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<sup>1</sup> According to Eakin *et al.* (2014), two types of capacities exist. Generic capacities enable decision-making and actions for general development pathways and specific capacities enable decision-making and actions for specific change such as the one required for implementing energy efficiency and sustainability. These specific capacities are often not evident within the existing demographic and socioeconomic characteristics of a population.

sustainability, but instead takes place within a broader adaptation pathway with an expanded, dynamic and non-linear decision-making space (Kläy *et al.*, 2015). Notably, decision-making and governance issues are beginning to be considered in sustainable transformations, but multi-level governance issues especially for effective systemic outcomes linking multi-dimensional sustainability have not been addressed to date (Nalau *et al.*, 2015).

Drawing on the sustainable transformations literature, this paper interprets sustainable transformation as “long-term and restructuring processes – through intervention techniques – required to articulate multi-dimensional energy efficiency and sustainability objectives– in order to effectively overcome challenges of development pathways and direct alternative development pathways towards multi-dimensional sustainability opportunities”. This is in relation to the change required in the energy and resource consumption patterns, reduction of carbon emissions, and delivery of multi-dimensional sustainable development pathways. When calling for such a transformation, emphases are made on developing capabilities and reforming practices of decision-making to leverage sustainable transformations (Poli, 2015).

This paper proffers that sustainable transformations will be most effective by: (1) populating emerging strategic capabilities within an integrated complex adaptive and socio-technical governing framework and (2) drawing on correlated commonly agreed perspective and multi-framing representations of both experts and non-experts from transdisciplinarity research to be more apprehensive of the contextual specific reality in which transformations ultimately take place. This paper focuses primarily on the existing English housing system because here, transformations are particularly dominated by data collected for technological solutions (Killip, 2013). The following sections identify challenges posed by most evidence pertaining to sustainable transformations and highlight how these challenges could be overcome by explicitly populating emerging strategic interventions. These also encompass relationships of strategic component-elements as well as multi-framing representations. In this context, the discussion includes a conceptual model: Strategic tri-level relational interventions for delivering energy efficiency and sustainability (STRIDES) which makes an innovative contribution to the evidence base for delivering effective sustainable transformations.

## **2. Sustainable transformations – key challenges**

Synopses of sustainable transformations in general address the topic of evaluation – whether potential system transformations actually further sustainable development with respect to their starting points. These involve assessments of effectiveness and decision-making (Kates *et al.*, 2001; Pope *et al.*, 2004). Normally, assessments are based on the ‘triple-bottom-line’ approach. These assessments are not carried out in an ‘integrated’ fashion and raise concerns for their legitimacy, especially when their interpretations are considered in decision-making. Alternatively, assessment based on principles-based approach encourages positive steps or proactive actions while avoiding any adverse effects during the process of transformations (Gibson *et al.*, 2013). Therefore, principles-based approach signifies interactions between interventions and relevant prime multi-dimensional sustainability objectives and supports decision-making for sustainable transformations.



One of the criticisms of the established principles-based approach has been that these lack the capacity of offering alternatives to existing problems (Hajer and Wagenaar, 2003). Particularly in sustainable transformations, there can be a risk that alternative interventions are being governed by principles underpinning specific needs and interests of disparate domains of the systems (Walker *et al.*, 2006). In addition, the best alternative at hand may be challenged by internal as well external behavioural and institutional and organisational governance structures (Block and Paredis, 2013). Given this, the mismatch can be bridged if decision-making for implementing strategic interventions for sustainable transformations is explicitly considered in the context of overarching governing-rules and theoretical transformations including transformations in values and purposes, as well as considering the complexities of the current governance arrangements.

Implementing and integrating strategic interventions demands robust assessments of these interventions guided by a comprehensive analytical approach. These include assessments of actual outcomes, impacts on multi-dimensional sustainability and comprehension of learning for governing such interventions for future challenges of sustainable development. Thus, these assessments are not only important to know strategic outcomes, but also how these strategic interventions contribute to active participation of diverse system-agents, collaborative actions and institutional capacity building (Holden, 2010; Polk, 2011; Smedby and Neij, 2013). Embedding evidence on strategic interventions within overarching governing-rules of sustainable development have potential of contributing to a more holistic and integrated sustainable development perspective, recognising interconnectedness, collaboration and consensus-based processes facilitating alternative development pathways (EGM Report, United Nations).

While strategic interventions [as highlighted above] focus on principles-based approach for sustainable transformations, it is challenging because of societal systems have inherently multi-level, multi-organisational, and multi-stakeholder nature of governance arrangements (Wise *et al.*, 2014). Moreover, societal processes underpin unsustainable values, cultures and institutions, which do not fully allow consideration of wider values, cultures, and institutions that are required in governing rules underpinning decision-making for sustainable transformations (see Pahl-Wostl *et al.*, 2013). Therefore, the principles-based approach may not be desirable for multiple and deep uncertainties, dynamic interdependencies of wider values, cultures and institutions, cross-scale global and inter-generational problems, and decision-making in a governance structure having absolutely top-down or bottom-up governance (Voß *et al.*, 2007).

A number of studies have argued that approaches for sustainable transformations need paradigmatic shifts in framing and decision-making [individuals and collectives] to deliver effective sustainable transformations. These studies also signify viewing local societal systems as complex adaptive system in relation to wider complex global processes (see Bale *et al.*, 2015). In addition, there is a widespread recognition that sustainable transformations are required to underpin science and practice discourses (Gorddard *et al.*, 2016). Such advances are required to provide opportunities for a new aggregation of theories and practices, including modelling that can support effective decision-making in sustainable transformations of a complex adaptive system (Holtz *et al.*, 2015).

In addition to above, the approaches for sustainable transformations are required to overcome the limitation of previous assessment techniques that range from inability to change human behaviour through failures of governance arrangements and institutional disorganisation to inability to drive the change to leverage sustainable transformations (Amundsen *et al.*, 2010; Hammill and Tanner, 2011). Therefore, these approaches must have capacities of dealing with uncertainties, devolved decision-making and disputed values (Weaver *et al.*, 2013). In addition, these approaches must employ technological advances for management and the concept of ‘pathways’ to visualise transformations processes and be able to consider interdependencies of many variables of internal and external environment. These approaches need to be flexible, allow iterative management and accommodation of strategic future requirements (Haasnoot *et al.*, 2013).

In this context, broader conceptualisation of sustainable transformations presented by Wise *et al.* (2014) interface a number of factors including (a) various contexts [economic, environmental, social, political, institutional, cultural etc.]; (b) coordination of changes [outcomes] and responses [decision-making] across spatial scales; (c) processes, interactions and feedback within the temporal scales to facilitate the change overcoming the ‘lock-in’ characteristics; (d) evaluating mechanism to understand if the emergent properties are leading to desired outcome; and (e) recognising and understanding interdependencies of all these four factors and enabling sustainable transformations, particularly in consideration to core values, governing-rules and institutional capacities in which these processes occur. Given the importance of these factors, further sections investigate these issues to identify systemic interdependencies between local performances and national and global targets, dynamic networks within organisations and inter-organisational field and emergent decision-making processes that underpin emergent governing-rules for effective sustainable transformations.

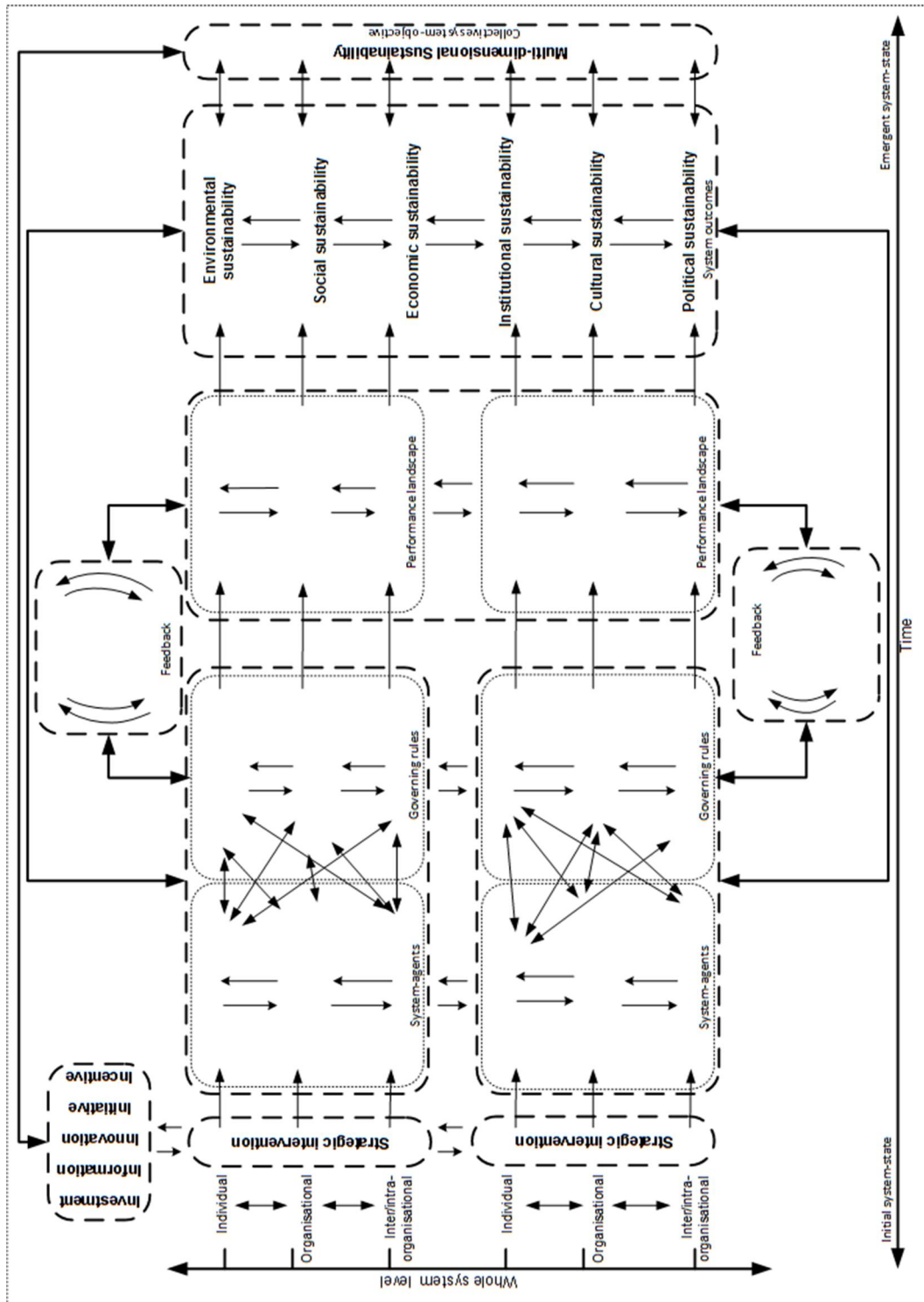
### **3. Research Methodology**

An effective response to sustainable transformations, therefore, requires engaging the research lens of transdisciplinarity (Nicolescu, 2008) adopting an integrated constructivist/interpretivism paradigm (Burrell and Morgan, 1979; Gray, 2014) and using an explicit mixed methods design. Following the identification of a list of critical barriers and of immediate relevance to the English housing sector (including its stakeholders and sustainable transformation), the priorities of the essential conditions was formally determined through an online questionnaire which contributed to systems-knowledge development. Two Delphi questionnaires, further, allowed for critical evaluation of strategies aligned with energy efficiency objectives and support sustainable transformations generating target-knowledge. A conceptual strategic engagement model for delivering energy efficiency initiatives within the English housing system incorporating evidence gathered from both system-knowledge and target-knowledge was developed through the focus-group discussion generating transformative-knowledge.

## 4. Research Findings

Figure 1: Tri-level relational governance structure

In practice, sustainable transformations would be substantially effective if they took more careful



account of the inherently multi-level, multi-organisational, and multi-stakeholder nature of governance arrangements – in many instances, integrating complex adaptive and socio-technical

governing arrangements will be just as important in shaping the success of an energy-efficiency initiative as the sustainability science, system innovation and system-transformation underpinning the broader conceptualisation of sustainable transformations. Therefore, the research findings provided suggestions for how building strategic capabilities with tri-level decision-making framework can address critical challenges in accounting for the wider complex governance context in multi-dimensional sustainable transformations.

In terms of challenges, first, the initiatives should underpin multi-dimensional sustainability principles drawing on a broad consensus backing by major stakeholders having capability for decision-making and delivering effective sustainable transformations not only at individual level but also contribute to full implementation as well as enforcement for sustainability deliverables at global, European or national level. Second, the governance and planning of transformation should be embedded within tri-level relational governance structure (Figure 1). Doing so implies that decisions will be informed by correlated commonly agreed perspectives, multi-framing representations of multi-level, multi-organisational, and multi-stakeholder nature of existing governance arrangements.

To meet these challenges, the first step, according to the proposed tri-level relational governance structure, is to implement strategic interventions in the context of individual, organisational, and inter/intra-organisational energy-efficiency and multi-dimensional sustainability targets/objectives. The multiple perspectives of the system-agents and their association with multi-dimensional sustainability that embodies economic, environmental, social, political, regulatory, cultural, technical and institutional dimensions are required to be reconsidered over and over and refined to ensure building of strategic capabilities for decision-making and sustainable transformations.

The second step will be to ensure that experts and non-experts stakeholders contribute in understanding the complexity of the English housing system going beyond the subsequent challenges posed by the transformation process. From the outset, each decision-maker should consider interdependence of the governing-rules of the system and relate to the system-objective that is valued in common. Therefore, sustainable transformations cannot take place in the existing governance structure but instead by understanding inter-relationships and building strategic capabilities that are critical for sustainable development of the whole housing sector. These strategic capabilities are those that encompass unified relationships of very important interventions and barriers identified by a number of disparate housing system-agents. As a consequence, there is a strong need to develop tri-level relational effective interventions.

## **5. Conclusions**

Sustainable transformations can be substantially more effective if they embrace the inherently multi-level, multi-organisational, and multi-stakeholder nature of governance arrangements. While individual transformations can be informed by solid empirical outcomes; this, on its own is typically insufficient in informing the strategic capabilities required for decision-making and learning as well as in delivering effective governance of sustainable transformation for the entire

sector. Given these issues, this paper highlighted the critical challenges in engaging the wider complex governance context for multi-dimensional sustainable transformations and provided suggestions for addressing these challenges.

The research lens of transdisciplinarity using an explicit mixed methods design maximises engagement and participation, providing multi-framing representations of the domains of housing providers, occupiers and regulators and in-depth understanding of the cognisant that are ‘fit for purpose’ and apprehensive of the contextual specific reality for sustainable transformations. In contrast to work by Gaziulusoy *et al.* 2015, who focus on integrating framing, this work fully acknowledges the conceptual modelling for explicitly and directly illustrating theoretical underpinnings. In addition, this research suggest that the use of integrating framing and systems-thinking might have benefits if they are used for the implications of emerging properties within multi-dimensional complex contexts. It thus can affect strategies for energy efficiency and sustainability in societal systems and leverage sustainable transformations.

While this paper provides a number of implications of the conceptual engagement model, for e.g. for explicitly and directly illustrating theoretical underpinnings and generating learning for the system-stakeholders, it just begins to establish a model of how emerging properties are identify through engagement and participatory processes. It therefore describes an initial state of the system, a starting point of research. Thus, the suggested conceptual model can be applied to multi-level governance structure and building capabilities for shared and correlated objectives. Future work can also focus on analysing in depth understanding of each emerging strategic process to relate tri-level governance structure to what participants know already.

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# Sustainable Food Environments

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## Abstract

The relationship between food, the built environment and sustainability has not been widely researched. However, food consumption patterns can have a significantly negative impact on the environment, as well as beneficial impacts on human health and well-being. For instance, locally grown food has much lower carbon emissions associated with it compared to imported, highly processed, foods. Similarly, a balanced and nutritious diet ensures health and wellbeing while a poor diet leads to increased susceptibility to ill-health and disease. Achieving sustainability will therefore require food that both promotes health and has low negative environmental impacts (sustainable foods). Built environments can hinder, or support, access to these foods.

This paper draws on the Ecological Footprint measure to define preferred, or more sustainable, food and diets. In turn, this is analysed to determine built environment configurations and characteristics that enable these diets and promote access to sustainable foods. This analysis is distilled into simple ‘sustainable food environment criteria’ which can be used to assess built environments. These criteria are investigated by applying these to a neighbourhood in Pretoria, South Africa. The paper finds that the sustainable food environment criteria developed provide a useful measure of the extent to which built environments promote sustainable diets and recommends that further research is undertaken in this field.

**Keywords:** Food, Built Environments, Ecological Footprint, Neighbourhoods

# **Sustainable Food Environments**

## **1. Introduction**

The problem with many definitions of sustainability is that they are not specific and do not provide clear quantified targets. Without a specific 'end' to be aimed at, it is very difficult to define the 'means' by which this will be achieved (Costanza and Patten, 1995). Therefore in order to make progress in achieving sustainability, an effective definition is required (Robèrt et al, 2002)

In this paper, a definition of sustainability developed by the World Life Fund (WWF) is adopted. This sets specific Human Development Index and Ecological Footprint targets that must be attained in order for sustainability to be achieved (World Wild Life Fund, 2006). This paper analyses this definition in order to understand the implications of this for food and for the built environment.

A Household Ecological Footprint Calculator is used to understand the nature and characteristics of a low ecological footprint diet (Redefining Progress 2003). Once determined, low ecological footprint diets are analysed to extrapolate the implications for households and for the local built environment. In turn this forms the basis for the development of a simple set of 'sustainable food environment' assessment criteria. These criteria are investigated by applying them to a household and neighbourhood in Pretoria, South Africa. The results of this assessment, and a review of the methodology and criteria, are discussed in order to evaluate the value of the approach. Finally, the paper draws conclusions and makes recommendations for further study.

## **2. Defining sustainability**

The Human Development Index (HDI) was developed by the United Nations and is extensively applied as a measure of quality of life (United Nations Development Programme, 2007). The HDI is based on:

- A long healthy life, measured by life expectancy at birth
- Knowledge, measured by the adult literacy rate and combined primary, secondary, and tertiary gross enrolment ratio
- A decent standard of living, as measure by the GDP per capital in purchasing power parity (PPP) in terms of US dollars

The WWF definition of sustainability indicates that the achievement of an HDI of 0.8, or above, should be regarded as evidence that minimum acceptable standards of quality of life have been achieved (World Wild Life Fund, 2006).

An ecological footprint is the amount of land and sea required to provide the resources that a human population consumes and to absorb the corresponding waste. Consumption of resources and production of waste and emissions used in the Footprint are drawn from the following areas:

- Food, measured in type and amount of food consumed
- Shelter, measured in size, utilization and energy consumption
- Mobility, measured in type of transport used and distances travelled
- Goods, measured in type and quantity consumed
- Services, measured in type and quantity consumed
- Waste, measured in type and quantity produced

The area of land and sea required for each of these areas is calculated in global hectares (gha) and added together to provide an overall ecological footprint per person (Wackernagel and Yount, 2000). The Earth's surface area is used to define limits for personal ecological footprints and this is calculated by dividing the Earth's carrying capacity by the size of the human population. In 2006, this calculation resulted in a limitation of 1.8 global hectares (gha) per person (World Wild Life Fund, 2006).

This definition provides clear criteria and targets that can analysed to understand the relationship between food, the built environment and sustainability. This analysis is used to contribute towards the development of indicators of 'built environment capacity' to support the achievement of reduced ecological footprints for food consumption (Kitzes et al, 2009)

### **3. Food**

Food can be defined as 'any nutritious substance that people .... eat or drink ...in order to maintain life and growth' (Oxford Dictionaries, 2015). Aspects of food consumption which are measured for ecological footprint calculations are identified in a Household Ecological Footprint Calculator (Redefining Progress, 2003). These are listed in table 1.

*Table 1. Household Ecological Footprint Calculator food types*

*Vegetables, potatoes & fruit*  
*Bread and bakery products*  
*Flour, rice, noodles, cereal products (exc maize)*  
*Maize*  
*Beans and other dried pulses*  
*Milk, cream, yogurt, sour cream*  
*Ice cream, other frozen dairy*  
*Cheese, butter*  
*Eggs [assumed to be 50 g each]*  
*Meat*  
     *Pork*  
     *Chicken, turkey*  
     *Beef*  
*Fish*  
*Sugar*  
*Vegetable oil (seed or olive oil)*  
*Margarine*  
*Coffee & tea*  
*Juice & wine*  
*Beer*  
*Garden [area used for food]*  
*Eating out*

### 3.1 The ecological footprint of food

Entering data into the Household Ecological Footprint Calculator can be used to understand existing patterns of food consumption within households and to calculate their ecological footprint (Redefining Progress, 2003). This assessment was carried out for a household of 5 people in Muckleneuk, Pretoria, South Africa, in October 2015. Muckleneuk is indicated in figure 1, later in the paper. The calculation indicates that the household has an overall ecological footprint of 6.7 gha/person, with food consisting of 1.5 gha/person, of this total. Food, in this instance, is responsible for about 20% of the ecological footprint of the household. The overall footprint of 6.7gha/person far exceeds the 1.8gha/person target required for sustainability and represents overconsumption (Rice J, 2008; Princen, 2002).

A review of the food criteria within the Household Ecological Footprint calculator can be used to determine measures which could be used to reduce the ecological footprint of food used within households, and ideally, ensure that these contribute to achieving the overall sustainability target of 1.8gha/ person.

### 3.2 Measures to promote sustainable diets

The following measures can be used to reduce the ecological footprint of food within households.

1. Locally produced, fresh vegetables and fruit are purchased in preference to other foodstuffs (Andersson and Lindroth, 2001)

2. Vegetarian sources of protein such as beans and pulses are purchased in preference to meat and fish.
3. Locally produced milk, cheese and eggs are purchased in preference to processed food products.
4. Margarine, oil, tea, coffee, beers, juice and wine, meat, fish and processed food items are only purchased once 1-3 items have been purchased and then purchased in limited quantities.
5. Food items 1 to 3 are available within 2km (Rundle et al, 2009; Gibberd 2015).
6. Food items 1 to 3 are affordable to local population.
7. Cultivated areas within the neighbourhood are used to produce fresh vegetables and fruit.
8. Eating out at restaurants is limited. Where this exists, restaurants with menus based on food types 1 to 3, are given preference.

Adopting these measures and recalculating the ecological footprint of the Muckleneuk household using the Ecological Footprint Calculator indicates that an ecological footprint for food of 0.3 to 0.4 gha can be achieved. This represents about 20% of the total household ecological footprint. Along with measures in the other areas (such as goods and services, shelter and transport) these actions would enable the achievement of the target 1.8gha, required for sustainability (World Wild Life Fund, 2006). Therefore these ‘sustainable food’ measures provide a set of requirements that built environments must meet.

## **4. Implications for the built environment**

Local availability has been shown to be a key influence on household food consumption patterns (Rundle et al, 2009; Gordon-larsen, 2014; Frank et al, 2007). However, it is also important to note that the availability of particular types of food do not necessarily mean that occupants of households will consume these foods (Gordon-larsen, 2014). So while built environments may not be able to *ensure* that sustainable diets are achieved, they can support this directly by enabling local access to sustainable food. It is likely that other measures, coupled with local availability, such as ‘promotion, education and incentives’ will also be required for sustainable diets (Gordon-larsen, 2014).

### **4.1 Built environment requirements for sustainable diets**

The ‘Measures to promote sustainable diets’ outlined above can be used to define built environment and neighbourhood requirements. These are listed below.

1. Neighbourhoods should include a retailer of, or access to, fresh vegetables, fruit, beans and pulses, bakery products and milk, cheese and eggs. The cost of these products should be affordable for the local population.
2. Highly processed, non-local food products, oil, tea, coffee, beers, juice and wine, meat and fish should be more difficult to access than the food types in 1.

3. A proportion of household gardens and open space within the neighbourhood should be allocated to vegetable and fruit production.
4. Restaurants with menus based on locally produced fruit, vegetables and include vegetarian, dairy and egg-based dishes, should be given preference over restaurants which have menu based on high ecological footprint items such as meat and imported items.

## 5. Sustainable food environment criteria

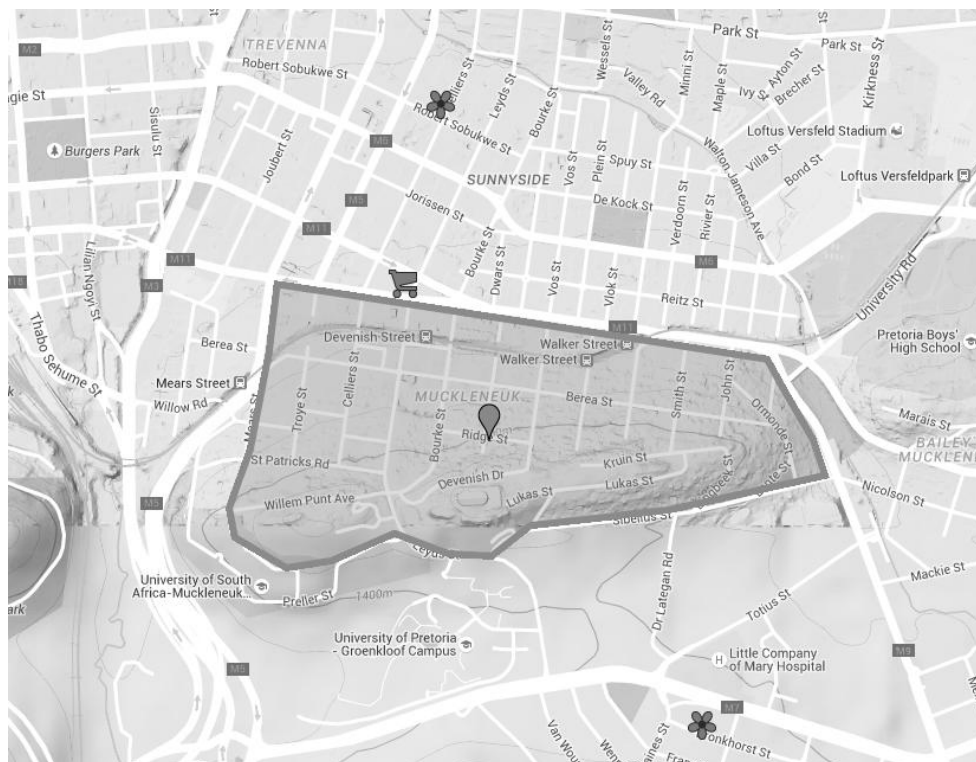
Built environment and neighbourhood requirements to promote access to low ecological footprint food can be translated into a simple assessment framework, as illustrated in table 2. In this framework, 'locally produced' and 'local', means that the item is produced within the country and is not imported from another country. This aspect could be refined in future frameworks to refer to a specific distance, such as 100km from the retailer, but this will considerably increase the complexity of the assessment. The term 'neighbourhood' in the framework refers to the area surrounding a household.

*Table 2. Sustainable food environment criteria*

<i>Criteria</i>	
<i>FO1</i>	<i>There is access to / a retailer of locally produced fresh vegetables and fruit within 2 km. The cost of these products is affordable for the local population.</i>
<i>FO2</i>	<i>There is access to / a retailer of locally produced beans and pulses within 2 km. The cost of these products is affordable for the local population.</i>
<i>FO3</i>	<i>There is access to / a retailer of bakery products within the 2km. The cost of these products is affordable for the local population.</i>
<i>FO4</i>	<i>There is access to / a retailer of locally produced milk, cheese and eggs within the 2 km. The cost of these products is affordable for the local population.</i>
<i>FO5</i>	<i>Access to products such as highly processed and non-local foods as well as oil, tea, coffee, beers, juice and wine, meat and fish are more difficult to access than food types in FO 1-4.</i>
<i>FO6</i>	<i>Fifty per cent of the cultivated area within the neighbourhood is used to produce fresh vegetables and fruit.</i>
<i>FO 7</i>	<i>Restaurants with menus based on locally produced fruit, vegetables and include vegetarian and dairy and egg-based dishes, should be given preferential locations over restaurants which have menu based on high ecological footprint items such as meat and imported items.</i>

### 5.1 Mapping criteria on to a neighbourhood

The criteria in table 2 can be investigated by applying these to the neighbourhood identified earlier in the paper. The selected neighbourhood is Muckleneuk in Pretoria, South Africa (latitude - 25.76329, longitude 28.20816) and is represented by the shaded area indicated in figure 1.



*Figure 1. Map of neighbourhood indicating food retailers*

A location in the centre of the neighbourhood is identified (pointer). Facilities required for a low ecological food footprint such as local retailer(s) of low ecological food are then identified and marked on the map. Facilities that are within the neighbourhood, or nearby, are marked on the map in figure 1 using icons. Icons used are a daisy for a green grocer and a shopping trolley for super market. The distance of these facilities to the centre of the neighbourhood is also measured and recorded in the assessment and captured in table 3 below. The first column of table 3 indicates the assessment criteria for built environment aspects of food. The second column indicates the assessment. This includes the distance of the facilities from the centre of the neighbourhood in metres and provides a key to the symbols on the map in brackets (ie daisy). The third column indicates whether the criterion was achieved for the Muckleneuk neighbourhood.

*Table 3: Sustainable food assessment*

<i>Criteria</i>		<i>Assessment</i>	<i>Criterion achieved?</i>
<i>FOI</i>	<i>There is access to / a retailer of locally produced fresh vegetables and fruit within 2 km. The cost of these products is affordable for the local population.</i>	<i>The nearest retailer of fresh vegetables and fruit is 1720 m away. (daisy symbol)</i>	<i>Yes</i>

FO2	<i>There is access to / a retailer of locally produced beans and pulses within 2 km. The cost of these products is affordable for the local population.</i>	<i>The nearest retailer of beans and pulses is 930 m away. (shopping trolley symbol)</i>	<i>Yes</i>
FO3	<i>There is access to / a retailer of bakery products within the 2km. The cost of these products is affordable for the local population.</i>	<i>The retailer of bakery products is 930 m away. (shopping trolley symbol)</i>	<i>Yes</i>
FO4	<i>There is access to / a retailer of locally produced milk, cheese and eggs within the 2 km. The cost of these products is affordable for the local population.</i>	<i>The retailer of milk, cheese and eggs is 930 m away. (shopping trolley symbol)</i>	<i>Yes</i>
FO5	<i>Access to products such as highly processed and non-local foods as well as oil, tea, coffee, beers, juice and wine, meat and fish are more difficult to access than food types in FO 1-4.</i>	<i>The retailer of oil, tea, coffee, beers, juice and wine, meat and fish is 930 m away. This retailer is easier to access than some the retailers in FO1-4. (shopping trolley symbol)</i>	<i>No</i>
FO6	<i>Fifty per cent of the cultivated area within the neighbourhood is used to produce fresh vegetables and fruit.</i>	<i>The area used to produce fresh vegetables and fruit is less than 10% of the cultivated area which consists of lawns, shrubs and non-fruit bearing trees.</i>	<i>No</i>
FO7	<i>Restaurants with menus based on locally produced fruit, vegetables and include vegetarian and dairy and egg-based dishes, should be given preferential locations over restaurants which have menu based on high ecological footprint items such as meat and imported items.</i>	<i>No local restaurants have menus based on locally produced fruit, vegetables and include vegetarian and dairy and egg-based dishes.</i>	<i>No</i>

## 6. Discussion

A number of interesting findings emerge from the use of the proposed methodology and the assessment framework. These can be discussed with a view to improving the approach.

While it is important that the ecological footprint of food is reduced, it is also important to ensure that diets have the correct nutritional content. This aspect is addressed to some extent in the Household Ecological Footprint Calculator which records the protein and calorie content of food consumed and compares this to recommended daily allowances (RDA) (Redefining Progress,



2003). This aspect of the calculator is helpful and could be developed further to include other essential elements of a diet such as vitamins.

Affordability in the assessment criteria has not been sufficiently defined. This should be developed and could be addressed in the following way. Affordability could be defined in terms of the monthly cost of a food item relative to the monthly income of the household. For instance, the affordability of fresh local vegetables could be determined by establishing the proportion of monthly household income that would be required to buy a month's supply of vegetables for the household.

Criterion FO6 raises a number of questions in relation to efficiency. For instance, it may be argued that household and neighbourhood gardens are inefficient and that food production is more efficient on large commercial farms. There are a number of counter arguments to this. Firstly, inputs such as water, fertiliser and labour, are likely to be consumed in household gardens and neighbourhood parks anyway to create lawns, flower beds and ornamental shrubberies. Using a proportion of these inputs for productive food production would therefore reduce overall ecological footprints. In addition, at a household and neighbourhood scale, cultivation is likely to be carried out largely by hand which will have a lower ecological footprint than mechanised approaches used in commercial farms.

Criteria in the framework refer to retailers being 'within 2km'. While this distance may be acceptable in some situations, this may not be the case for others (Gibberd, 2013). In particular, this distance may be regarded as too great in cold or hot climates and where households include children, infirm and elderly people. In these cases, the use of a shorter distance, such as 400m, which is used in some green building rating tools, may be more suitable (United States Green Building Council, 2015). It is interesting to note that if 400m is used, the Muckleneuk neighbourhood would not meet any of the sustainable food criteria indicated in table 3.

Finally, the methodology assumes that inhabitants will use the lowest ecological footprint food options. In reality this is not true; as people may consume higher ecological footprint food because this is cheaper, is seen to be more 'fashionable', or is easier to access. Therefore, in addition, to making low ecological footprint easy to access, it is also important to ensure that this is affordable and seen to be desirable (Gordon-larsen, 2014).

## **7. Conclusion and recommendations**

The study provides useful insight into how built environments may support the reduction of ecological footprints associated with food. While a number of criticisms can be levelled at the approach, it provides a simple way of assessing the extent to which the built environment may be configured to reduce food-related ecological footprints. It accepts that other factors, such as affordability and personal preference, may result in the capability of the local built environment to reduce ecological footprints not being used. These issues are important and should be addressed if the methodology is developed further.

## 7.1 Recommendations

From a review of the study the following recommendations are made:

- a. Household ecological footprint calculators should be developed to include defined minimum nutritional requirements for diets. This will help avoid the situation where locally available food may meet ecological footprint requirements but not be sufficient to maintain human health.
- b. The affordability aspect of the criteria needs to be designed. Affordability could be defined in terms of the monthly cost of specified food items as a proportion of household income. For instance, locally available fruit and vegetables could be classified as affordable where the cost of purchasing a month's supply for a household was less than, say, X% of the household income.
- c. The criteria related to the cultivation of vegetables and fruit within household gardens and within the neighbourhood requires further investigation. For instance, the proportion of cultivated area required for vegetable and fruit production may vary depending on local population densities, local climate, availability of water for irrigation and the productivity of soils (Andersson and Lindroth, 2001)
- d. The social capital value of local food retail facilities identified in this study should also be researched further. This should draw on work that links improved environmental efficiency in communities with higher social capital (Knight and Rosa, 2011).
- e. Sustainable food environment criteria from this study, particularly if further developed through recommendations (a to d) should be incorporated into built environment sustainability assessments tools, such as the Built Environment Sustainability Tool (BEST) and the Sustainable Building Assessment Tool (SBAT) (Gibberd, 2015).

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# Kampung Development for a Resilient City

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## Abstract

Kampung is self-developed settlements inhabited by low income class in Indonesia. In Surabaya, the second largest city of Indonesia, kampungs are retained and developed as a decent place to live with all of its uniqueness. Kampung Improvement Program (KIP) in Surabaya, for example, is purposed to raise awareness of the inhabitants, to empower and to improve their quality of life and their living environment independently. Physical improvements are conducted based on community awareness which in turn grow the community's sense of belonging. The improvement is sustainable and has significant result in improving the quality of life of the inhabitants as well as the quality of the settlement. In addition, awareness and self-reliance of the community can maintain the originality of neighbourhoods, and together they create a unique atmosphere in the city scale. Surabaya is growing as a metropolitan city, but also humanist by creating a decent living environment for all residents.

This research develops the concept of resilience that seeds from the kampung of Surabaya in dealing with problems and changes occur in urban areas. Vulnerable state is addressed by action in the form of prevention, adaptation and improvement to survive and, at the same time, to change without losing its identity, such as through Kampung Improvement Program.

Using qualitative descriptive method, this study examines the aspects of resilience found in the kampung which include preparedness, mitigation measures and response capabilities of the urban kampung. They are analyzed in the context of creating/improving the level of city resilience. This study shows that kampung as urban informal settlement is not a burden but a great value deserved to be improved to be able to contribute in creating resilient city. Surabaya can be an example for other cities that are building their resilience and have the same context with the city of Surabaya.

**Keywords:** low income settlement, kampung, city, resilience

# 1. Introduction

It is projected in 2025 that around 68% of the world population will live in urban areas. The carrying capacities of the city are decreased and triggered. Every city dweller makes efforts to survive. Residents of middle to high economic level might have no difficulty making an effort to earn a decent living. However the poor community might be forced to survive with all the limitations and the rigors of life in the city competition; to live in dense environments, inadequate dwelling and lacks of basic infrastructure.

Kampung is a form of indigenous settlement which developed without planning process mostly inhabited by lower middle income group. In many urban area of Indonesia, kampung is more dominant in comparison to formal settlement. Although mass housing development policy for low income group has been started and succeeded in Indonesia since 1974, self-help housing still has a great contribution in the provision of housing; contributes about 85% of housing delivery (Struyk, 1990). In comparison to village in rural area, kampung is far more compact and influenced by the city activity as the centre of trading and services.

Physically, kampung represents the concept of urban as the compact area in terms of population density and efficiency of land. Its high-density built-up area with minimal infrastructure is the main characteristics of the kampongs which at the beginning will lead to the impression of slum areas. However kampongs are rich with non-physical aspects, such as their culture and social bound. Kampongs provide a positive value to the city of diverse community i.e. origin, income, education, occupation, ethnicity, political affiliation, etc. This diversity allows the community to create and develop the principles of diversity, tolerance and solidarity.

Various studies indicate kampung are able to provide a positive contribution for development of Surabaya (Colombijn, 2010, Dick, 2003). Nowadays, approximately 70% of total population (3 million) is living in the kampongs Surabaya (City Government of Surabaya, 2012, Surabaya in Numbers, Statistic Bureau, 2015). A sustain kampung development program have been able to create viable and self-supporting settlements in Surabaya. The program is done to create a viable living environment with regard to the uniqueness of each kampung which includes physical aspects (house and surroundings) and non-physical ones (economics, management capability of the community, the quality of human resources, etc) (Silas, 2010, Building and Social Housing Foundation, 1993).

The kampung improvement program is carried out by improving the community capacity to improve the kampung physical condition. This program fosters their fighting spirits which sustains the program and improve their sense of belonging of the environment. Kampung Surabaya receives various national and international recognitions for providing a decent living environment for the lower income group in the pace of urbanisation and modernisation movement such as Aga Khan Award in 1986 for Kampung Kebalen (Silas, 2012).

## 2. Urban Resilience

Resilience is the capacity of a system (infrastructure, government, businesses, communities and individuals) to absorb disturbance, to undergo change arising from the disruption and to maintain the function, structure, identity and provide appropriate feedback (Longstaff et al, 2010). The concept of urban resilience (resilience city) has been developed from a social perspective. There are many aspects or variables to measure resilience. According to the Infrastructure Survey Tool (IST) developed by Argonne National Laboratory resilience within a community or region consists of five (5) aspects. They are 1) Economy, 2) Civil society, 3) The main Infrastructure, 4) Supply chains (dependencies) and 5) Government (related to emergency response services). Meanwhile to measure the resistance of an individual more accurately, there are four (4) main variables namely 1) Preparedness, 2) mitigation, 3) response capabilities and 4) recovery mechanisms.

Urban is defined as multi-dimensional dynamic activities, in which there are aspects of change, vulnerability, or even potential crisis. In rapidly urban development, kampungs need to survive as a decent living space for the inhabitants. It means they have to deal with rapid physical changes as well as the changing needs of the dwellers in line with the social, economic changes in many aspects of life. There are several key elements which related one another in building resilience, namely i) disaster preparedness, ii) the capacity to adapt, iii) empowerment and iv) the diversity of choice and security. Resilience can be established as the result of dynamic and holistic integration of those key elements.

## 3. Method

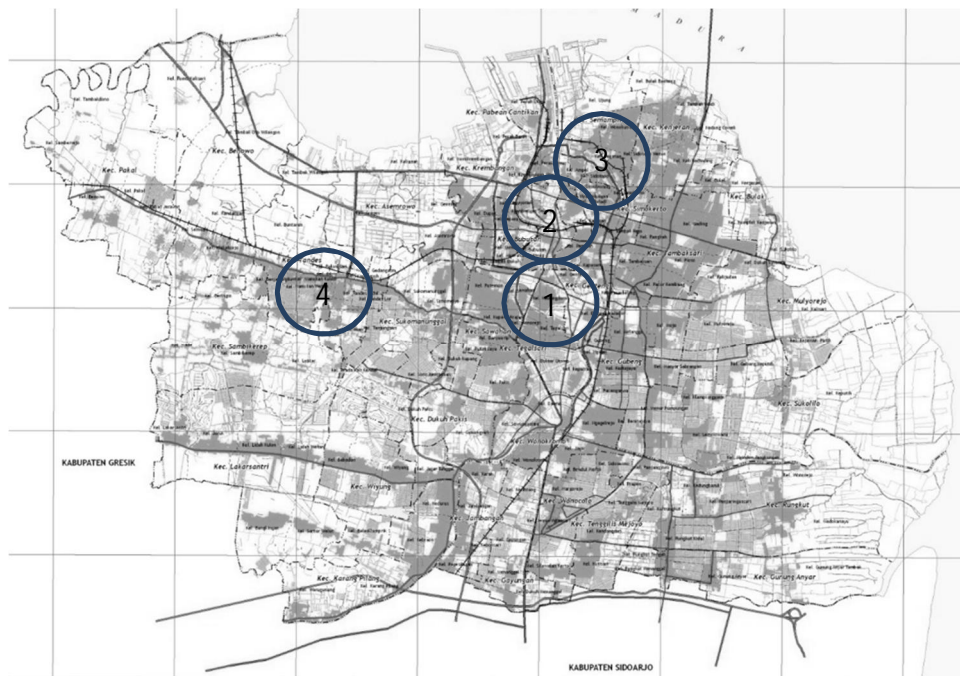
This study focus on how informal settlements build resilience in a neighbourhood level that contribute to the city level of resilience. The concept of urban resilience can help to understand the changes in complex systems and that a change is not just something urban necessity somewhat forced, but should also be adapted and managed. In building the resilience of the kampung this study will look at several key elements, namely, i) disaster preparedness, ii) the capacity to adapt, iii) empowerment and iv) the diversity of choice and security.

This study applies qualitative descriptive method. Variables of this study are the ability to manage threats, to adapt the changes, and to secure the adequacies. There are four kampung chosen as a case study which is expected to represent the character of the kampong in Surabaya (densely populated, minimum open space, its location, etc), its role for Surabaya, and the status of the community, namely:

1. Kampung Kaliasin at the centre of Surabaya, the old kampung sandwiched with the Central Business District Tunjungan.

2. Kampung Peneleh, located on the riverbank of Kalimas River, experienced the first kampung improvement program by the Dutch government. It is now developed into one of heritage kampung related to several historical events occurred in this area.
3. Kampung Ampel is an old kampung of Arab developed since the early period of Surabaya Kingdom. It is now as a pilgrim and tourist destination.
4. Kampung Gundih located on the bank of railroad, has a strategic location near wholesale trade centre and train station. Originally inhabited by criminals yet has been change into a green and clean kampung.

Figure 1 shows the settlement area in Surabaya. Kampung/self-help housing area is marked with the light colour while real estate is marked with a darker colour.



*Figure 1: Surabaya map and the research location*

Research location:

1. Kampung Kaliasin
2. Kampung Peneleh
3. Kampung Ampel
4. Kampung Gundih

## 4. Kampung of Surabaya

Surabaya covers an area of 326.37 km<sup>2</sup>, administratively is divided into 31 districts and 163 sub-districts. Most of the city area (80.72%) lies on lowland area (3-6 meters above sea level) and the rest is on hilly area of 20-50 m asl. The slope of the land ranges from 0-2% in the low-lying areas and 2-15% in the gently sloping hills. In 2015 the city' population is 3.269.931 with the average



growth is 0.6%. The projection of the next five years (2020) the population of Surabaya will reach 3.5million inhabitants and in 2030 will exceed 4 million people (Surabaya in Numbers, Statistic Bureau, 2015)

The high number of population with all their activities directly affects the capacity of regional development, increases the living competition, more expensive land, limits employment opportunities, declines environmental quality, as well as the fulfilment of infrastructure and facilities urbanity that must be met by the municipality. In term of housing policy, it appears that the government of Surabaya has a strong commitment to protect the kampongs as part of the city built environment to keep the city history and to provide living space for the lower-middle income group, in addition to develop new settlement area in accordance with the growing population.

It should be recognized that the kampung Surabaya has not only a passive role as the city heritage but also still an active one as the urban living space, shown by many awards received by the city of Surabaya for the role of the kampungs and its residents in the city development. As heritage, Kampung Surabaya has a unique characteristic showing the peculiarities of the city history, and the ability, effort, struggle and independent community spirit. Every kampung has its own uniqueness by geography, economic, social and cultural diverse. Awareness of the importance of environment makes the kampung clean and green, not just to ward off the negative impression. Surabaya has proved that the kampung is not slum areas. They are densely populated but look beautiful, complemented by a variety of basic amenities and well maintained by the residents.

As informal settlements, kampungs has a number of physical problems associated with the quality of the environment and poverty causes a lot of kampungs fall into categories of inadequate settlement. However, kampungs in Surabaya able to prove that the physical condition of the kampung can be upgraded through various kampung development and establishes an integrated urban infrastructure and facilities to serve the kampungs (Silas, 2012). The following is a short description of the kampungs chosen for this study.

#### 4.1. Kampung Kaliasin

Kampung Kaliasinin sub-district Tegalsari is one of the old kampung Surabaya characterized by Sholeh Mosque which is the second oldest Muhammadiyah mosque in Surabaya after Peneleh Mosque. The kampung is strategically located right behind commercial district of Jl. Tunjungan and serve as a residential area for blue collar workers, especially those of shopping centres and five stars hotels in Tunjungan. Kampung Kaliasin has several problems with poor public spaces and services, prone to flooding, environmental degradation, crime and commercialization of land. Figure 2 shows new houses are built adjacent to the old houses since there is limited space. The inhabitants use alley as a common place.



## 4.2. Kampung Peneleh

Kampung Peneleh in sub-district Peneleh has been developed since the period of Surabaya kingdom in the 15<sup>th</sup> century. A prince (Pinilih-Peneleh) was given a rank and a territory of the area between Pegirian River and Kalimas River. Kampung Peneleh was Sunan Ampel (a prominent Muslim preacher in Java) stopover before settling in kampung Ampel (Silas, 2012). It is also the settlement of several nationalist prominent, such as young Soekarno, the Indonesian first president.

Kampung Peneleh location is close to the city hall, commercial area, and revitalised waterfront area. Some buildings in the kampung have been enlisted as heritage buildings and in adjacent to an old Dutch cemetery which has a distinct forms. The kampung is relatively in good order with majority of the buildings in good condition. This kampung has several challenges, mainly the housing's land status and its very dense population. Figure 3 shows the Dutch old graveyard located next to the kampung and the example condition of old and new houses in Kampung Peneleh.



*Figure 3. Kampung Peneleh*

## 4.3. Kampung Ampel

Similar to Kampung Peneleh, Kampung Ampel in sub-district Ampel is also in the old part of Surabaya. While Dutch took place on the western part of Kalimas Riverbank (previously place of the Surabaya palace), the Arab, Chinese, Malay and other ethnics were living on the eastern riverbank. Kampung Ampel was the settlement of Arab community and the centre of the early spread of Islam in Java.

Nowadays the kampung has been developed as a tourist area particularly for the pilgrim and from this activity residents can improve the quality of settlements, physical and non-physical. However there are several challenges such as susceptible to crime, not well organized vendors, loading dock activities which cause congestion. Figure 4 shows an alley to/from Ampel Mosque with small vendors in comparison to a quieter alley, both located in Kampung Ampel.



*Figure 4. Kampung Ampel*

#### **4.4. Kampung Gundih**

Kampung Gundih in sub-district Gundih has been transformed from a ‘criminal’ kampung in 1990’s into one of the winners of ‘best of the best kampung Surabaya’ in 2010 (Silas, 2012). The kampung is surrounded by various region-scale facilities trade areas such as Surabaya Wholesale Center and Pasar Turi Train Station. Their works on environmental management such as greening, domestic waste management and domestic waste water treatment become one of their prominent works. The kampung has also various social activities which social awareness and strengthen the community bound. However because of its location kampung Gundih attracts many investors to develop the area to be a commercial area.



*Figure 5. The Kampung Gundih*

## 5. Discussion

Surabaya as one of the metropolitan cities in Indonesian faces severe challenges as the rapid globalization and modernisation. *Kampung* which is home to the majority of the city residents face the vulnerability of the environmental, economic, and social and culture dimensions. Vulnerability in the environmental dimension is the focus of this study with consideration to strong linkages with the built environment (residential area).

*Kampung* is a form of settlement that developed organically by the community, so that the buildings pattern tends to be irregular. It is home to people with diverse cultural backgrounds, economic, education and customs. The diversity of the community creates the kampung uniqueness if managed properly but lead to vulnerability if no tolerance among the fellow inhabitants. Identification of *kampung* vulnerabilities is based on the results of field observations and the synthesis of interviews with community leaders on the kampung current condition and the challenges potentially experienced by the inhabitants within the next decade period. In each *kampung* identified vulnerabilities caused by 3 (three) aspects of location of the kampung, economic, and social structure and cultural characteristics of the community.

### 5.1. Kampung Kaliasin Resilience

Behind buildings of a strategic area called Tunjungan with numerous malls and shopping centres, five-star hotels and apartments, and high-rise office buildings there are several kampungs. One of them is Kampung Kaliasin. The kampung is densely populated because most of the houses are also boarding houses for blue collar workers of Tunjungan business district. The area of Kampung Kaliasin can mainly be divided into two types; (1) The region with small building, normally accessible by foot and motorcycles, (2) the region with bigger buildings usually can be accessed by car (one way). The density level of this kampung is very high; makes majority of houses has neither yard, nor space between buildings. This condition makes the kampung vulnerable to fire and flood, low occupancy comfort level and may cause the emergence of slums.

Table 1: Forms of Resilience in Kampung Kaliasin

Vulnerability	Form of Resilience
Environmental	There is no environment communal activity particularly greening in Kampung Kaliasin because of land limitation which means that additional fund is needed to provide media for the plants. Thus domestic waste management is conducted on household basis. <i>Gotong royong</i> , a traditional communal work especially to clean their living environment is periodically conducted.
Social	Kampung Kaliasin housed a large number of blue collar worker of the Tunjungan CBD. The kampung leaders (formal and informal) have a mutual understanding with the managements of the surrounding buildings, in the

	forms of supporting community social events. Permanent inhabitants have kampung rules to guide the temporary occupants living in harmony in the kampung, such as the boarding owner has to report the neighbourhood leader everytime he accept a new person at the latest in 2X24 hours a long with the ID copy of the guess, no motorbike allowed to pass in the alley after 10.00 pm, in certain alleys there are no motorbike allowed at all (mostly those of very narrow or place to play for the children), etc.Theclose social ties between the two groups of inhabitant not only build a living harmony but also reduce the criminal rate in the kampung because in the very limited space they are known each other.
Economy	There are numbers and variations of small house based enterprises that providegroceries, food and services not only for the temporary inhabitants but also for the CBD blue collar workers in general.

## 5.2. Kampung Peneleh Resilience

Kampung Peneleh has a very strategic geographic position. The kampung is easily reached from the City Hall, Tunjungan central business district and various city facilities such as shopping (Atum shopping centre and Pasar Turi Wholesale marker), recreation (Tugu Pahlawan museum), art and entertainment (Centre for culture and arts Surabaya, the Youth Park and the Surabaya Amusement Park). In addition to those facilities, Kampung Peneleh is located close to the revitalisation area of Kalimas River which is also planned as a cultural tourist destination.

*Table 2: Forms of Resilience in Kampung Peneleh*

<b>Vulnerability</b>	<b>Form of Resilience</b>
Environmental	<p>Similar to Kampung Kaliasin, there is communal works on environmental management in Kampung Peneleh, but people awareness on greening and waste management is quite high.</p> <p>The community also aware on heritage protection by maintaining their environment. On an occation the community refused a program (alley pavementation) that will change the level of the alleys which lead to reducing the height of the buildings and covering the works of the first KIP in Surabaya.</p>
Social	The peculiarities of the kampung should be emphasized not on what is seen through any material object, but on the cultural activities undertaken by its citizens. Various activities of Kampung Peneleh community are conducted either in a private physical space (home, meeting rooms, etc.) as well as in public spaces such as roads, mosque, etc.

	Many typical Peneleh community activities could be seeded to be developed as tourist activities. Uniqueness formed hereditary with cultural elements from many ethnics (Java, Madura, Arabic, Chinese, etc.) are one of the cultural distinctiveness of Kampung Peneleh.
Economy	<p>In an effort to meet the needs of everyday life, the inhabitants establish small-medium home-based businesses which can be grouped as follows:</p> <p>A. Manufacturing Enterprises, processing of raw products into finished products, such as sewing clothes, veils and pillowcases, leather and plastic bags for children, food processing such as bread, fish crackers, traditional chips and cakes, traditional herbal drink, etc.</p> <p>B. Selling, providing products and services such as production of silk screening, plaques, pennant and business cards, printing, furniture, upholstery sofa or car seat making, various courses, beauty salon, computer rentals, photocopy, etc.</p>

### 5.3. Kampung Ampel Resilience

Kampung Ampel is a residential area of Arab community. The kampung gains its name from a famous Islam priest in Java –Sunan Ampel- who stayed in the Kampung. In the middle of the kampung is located an old Ampel Mosque and Graveyard, a significant pilgrim destination in Java particularly in the fasting month and the death anniversary of Sunan Ampel.

Kampung Ampel community still bond to Islamic culture, thus the settlement layout and housing plan are influenced by Islamic values. Similar to the previous described kampung, Kampung Ampel has a high level of building density, but the community is relatively more inclusive in comparison to the other chosen kampungs.

*Table 3: Forms of Resilience in Kampung Ampel*

Vulnerability	Form of Resilience
Environmental	<p>There is communal movement for greening and waste management in Kampung Ampel. Awareness on waste management makes the community to delegate it to other parties who clean the kampung and conduct 3R. Thus the kampung is clean and tidy.</p> <p>Circulation pattern of the settlement is like a labyrinth, is still used as a main access to the Ampel Mosque and Graveyard which in the central of the settlement. Architectural distinctiveness of Kampung Ampel is still well</p>

	maintained. Unique architecture is an inseparable element in the development of the kampung as a tourist destination.
Social	Kampung Ampel is a complex area, serves residential, trading and tourism purposes. All the functions create a unique atmosphere of the kampung with an interesting blended cultures of Arab and Java. To keep the harmony within the community, they make a commitment to limit new residents to settlement.
Economy	Since 1972, Sunan Ampel Mosque has been developed as a religious tourist destination by the Surabaya City Government. Along with its development more trading and services activities have been also flourished around mosque area, ranging from muslim clothes, prayer appliances, accessories- mostly produced by locals, and traditional Middle East foods.

## 5.4. Kampung Gundih

Kampung Gundih location is next to a train station that connects main cities in Java, and a large-scale trade area that serves as far as Kalimantan dan Papua, the eastern part of Indonesia. The kampung is passed by a primary arterial road leading out of the city highway access. Additionally, Kampung Gundih is adjacent to railroad tracks which most probably make it the living area of criminals (pickpockets, drug dealers, etc) in the 1990's. Only later an informal leader started to make changes, the kampung becomes prominent with their works on environmental management.

Kampung Gundih community is dominated by Javanese and Madurese ethnic with diverse cultural, economic, educational and customs backgrounds. The diversity can potentially lead to vulnerability of social conflict in the absence of a mutual understanding among fellow inhabitants. Moreover as the location is very strategic makes the house not only serves for a place to live but also for business which need more control.

*Table 4: Forms of Resilience in Kampung Gundih*

Vulnerability	Form of Resilience
Environmental	<p>To improve environment quality in Kampung Gundih, environmental management is carried out not only in aspects of greening the kampung, but also in the management of household solid and water waste.</p> <p>Solid waste management in Kampung Gundih is conducted through the 3R (reduce, reuse, and recycle) practice, meanwhile domestic grey water management is implemented by a simple grey water treatment equipment, which so far 16 units has been installed serving about 1200 houses.</p>

Social	At the lower level, each neighbourhood has at least one organization with regular activities for the inhabitants. All community in Kampung Gundih, despite of gender and age, have a fairly high level of participation in various communal activities such as communal work to clean the kampung, Sunday morning exercise, baby/toddler and elderly health group, etc. This makes the kampung development planning and program can be easily disseminated, discussed and implemented. There are also a variety of community organizations to facilitate the channelling aspirations related to the kampung development.
Economy	The strategic location of Kampung Gundih provides employment and home-based business opportunities. Moreover the success of environmental management in Kampung Gundih has attracted other local governments and community organisation as well as foreigners (mostly students and researchers) to come to the kampung. This provides business opportunities for the inhabitants such as home stay, souvenir, culinary etc. On the other hand, the city government also involves. Empowerment of women is intensified through education and training activities, micro credit as capital support is provided so that the results of training can be developed into new businesses, etc.

## 6. Conclusions

This study formulates the factors that cause the emergence of resistance (resilience) of the kampung communities that can be deployed in urban scale to support and create the city resilience to keep a decent living environment, livability and competitiveness both regionally and globally.

The research shows that each aspect of kampung resilience contributes to the city resilience. Environmental management in Kampung contributes to the improvement of residential comfort, to anticipate floods and fires. Another benefit of the environmental management is to increase the beauty of the kampung. Waste management conducted through the 3R (reduce, reuse, and recycle) program is able to reduce the volume of waste dumped in landfill area up to 83.34%. It is a great contribution to the resilience of the city in anticipation of potential disasters (flooding, outbreaks of disease, slum, etc.). Waste water management is beneficial to maintain cleanliness and health of the environment, anticipation of potential flooding, and reduce the use of water taps.

Social resilience contributes to the public awareness of the kampung condition and situation, and in turn to the city. It is not only building a good sense of place of their kampungs and the city but in general social resilience will keep the identity of the city as a place for various ethnics. Meanwhile economic resilience not only can be seen as a way of reducing unemployment rate but it is a way of low income community contributing to the city economic development.

The problems in kampungs as an urban settlement such as sub-standard housing, poor environmental condition, flooding, and poor sanitation influence the carrying capacity of the city. On the other hand the research shows that the resilience appears in the kampungs of Surabaya are



supporting the creation of a viable, livable and competitive city. It shows that kampungs have capabilities to overcome problems and changes occurred in urban areas without losing its identity and is able to survive in the midst of urban development even improving its condition.

*Table 5: Kampung Resilience Contribution*

<b>Vulnerability</b>	<b>Kampung Resilience</b>	<b>Contribution to the City Resilience</b>
Environment	Greening, domestic waste and grey water management	Improvement of community health level and living comfort, free from flood, fire and slums, forming a positive image of the kampunng, reducing quantity of waste processed in the city level.
Social	Social security by high level of public participation, various forms of social organization and communal activities	Avoiding conflicts among communities and ethnict, increased security, reducing criminal rate
Economic	Economic security by small business, productive housing, and environmental economics	Reducing economic uncertainty, the utilization of local resources, economic community empowerment

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# Sustainability by improving energy efficiency in traditional housing in Kosovo

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## Abstract

The objective of this paper is to identify and evaluate aspects of sustainability by improving the energy efficiency of traditional housing in Kosovo. The refurbishment of traditional houses is looked from different sustainable perspectives, like sustainable occupancy, sustainable environmental protection, sustainable tourism, and as learning case for urban planners, architects and real estate experts 1.

It is acknowledged that master artisans of traditional architecture in Kosovo were conscious of the sustainability parameters in designing and constructing traditional houses in villages and rural areas. Efficiency in the use of space, building location and orientation, design of the buildings, functionality of inner spaces, the layout of windows and use of materials have been important from the traditional old buildings. Traditional housing today, does not fulfil the needs and requirements regarding energy efficiency and comfort, as there is not sufficient insulation and heating. Rational use of space in neighbourhood creation, density within a city, connectivity with other neighbourhoods and the rest of the city, accessibility, a careful approach to environment, proper orientation of buildings to enable wind flow through the city, should also be identified as part of the sustainable urban development.

**Keywords:** sustainability, energy efficiency, traditional housing refurbishment, passive design, inner city rehabilitation,

# 1. Introduction

This paper is prepared within in the framework of joint cooperation project “SEEB – Sustainable Energy Efficient Buildings” between Kosovo and Norway, where have looked at case studies of existing traditional houses to find relevant and suitable measures to improve the energy efficiency and indoor comfort in the traditional houses. Through the energy analysis of refurbishment, we have found recommendations for solutions for energy improvements through passive design. The needs for refurbishment have to take into account the historic values and sustainable qualities of the buildings and historic urban areas. The majority of energy in Kosovo is used for residential needs. The absolute majority of houses in Kosovo, including old and new buildings, are not energy efficient. Furthermore, a large part of the houses and apartments in Kosovo use electrical energy for heating, causing energy efficiency to be at an alarmingly low level. Kosovo authorities have begun planning and drafting public policies related to efficiency based more on the requests made by the European Union rather than on the basic need for efficiency.

Prizren city in Kosovo, is an ancient city and have in its core or central district, the historic nutshell (downtown of the city), compoof cultural heritage buildings, mainly of traditional houses as well as public buildings. Houses are poorly inhabited (mainly empty), with the tendency to either be demolished and newly reconstructed or being left uninhabited, because of poor living conditions, poor living conditions.

The main objective of this study is to analyze possible measures in traditional houses in Prizren /Kosovo and compare them vs sustainability indicators, socio-economic and physical/environmental indicators. Improvements in energy efficiency in traditional houses in Prizren , are seen as appropriate measures, towards reaching other different sustainable goals than of only comfort. This is seen as an initial step, important and useful with big outcome results for the city, region, culture, economy etc.

From most recent data from the Conservation Plan of the City of Prizren, 2007 it is found that many of traditional houses in the city district core were have been demolished or left un-inhabited, from the main reason – to be newly rebuilt. The main driver of these actions are due to higher economic income benefits to the owners of the houses, when renting a new house. New designed houses in downtown of the city, (previosly with traditional design), do not obey on the traditional design and architecture, what is a threat as perceived by the owner-interviewe of this study: “there is a loss of the cultural heritage, loss of the city spirit” (Int. #7, 2015). The refurbishment of existing buildings is a neglected subject within sustainable architecture, where attention is usually focused on new buildings. Demolition is an option but the alternative of refurbishment is starting to be seen as more sustainable in terms of architectural value, materials use, neighbourhood disruption and waste disposal. Building new is more carbon intensive and carries many wider environmental impacts. In addition, the potential impact of low energy refurbishment is much greener than that of new build, since there are many more existing buildings that will be built in the next 10-20 years, the period over which many CO2 emission targets apply (Baker, 2009).

## 2. Theoretical background

### 2.1. Literature review

The urban development of historic cities is very challenging, especially when it comes to inner city rehabilitation, which is composed of historic area-downtown of the Prizren city. This is due to the need for a more rational/efficient use of space on behalf of redevelopment, but in the other aspect of traditional buildings that need refurbishment as to keep them in use, whereas rebuilt of them seems as more costly and inefficient solution. Sustainable development is seen according to Häkkinen (2012) that nothing can go ahead without radical changes in architecture, construction and spatial planning, a huge drive to conserve energy, increase efficiency and create zero-carbon buildings, all of which are vital in reducing the environmental impacts of buildings. As stated by Bokalders and Block (2010), planning a sustainable society requires a holistic approach in which we learn from and cooperate with nature. Urban development as cautious exploitation of resources can be understood from the fundamental principles for environmental sustainability. Sustainable society as cautious lifestyle should take into consideration that the transition to sustainable technology and renewable energy sources is not enough to achieve sustainable development. It should include a change of lifestyle (Bokalders and Block, 2010).

Environmental cities are cities with the focal point of the energy use and at the same time, the solution to energy efficiency and reduction of pollution. Conventional wisdom about the environmental impact of cities holds urbanization and environmental quality at odds, “the building sector of today has an oversized ecological footprint, being the single largest contributor to global greenhouse gas emissions and is responsible for more than a third of global resource consumption” (Meyer, 2013).

**Baeli (2013)** states that the housing stock represents some of the oldest in Europe with 55%. Therefore, the green buildings and residential retrofits are necessary to decrease rising levels of greenhouses gases. Residential buildings are seen as a part of the solution too, where retrofit is participating in the reduction of emissions, avoiding the dilapidation of buildings that have become uninhabitable, helping to future-proof houses against the risks of fuel poverty, and providing comfort for occupants. As a solution, **Baeli (2013)** sees ensuring the use of old houses in continuation, including financial investment to avoid dilapidation, ensuring their representativeness, cultural identity, and at the same time delivering the levels of reduction in energy use. Retrofit options are more preferable than demolition and a complete rebuild can be recommended from different reasons. A more societal point of view shows the retrofit can be more acceptable than a complete rebuild, as it could potentially create long-term employment. From a psychological perspective the replacement of components and tailoring space organization to new uses can improve environmental quality and satisfaction. Implications for change of use is an important factor as refurbishment is often accompanied by change of use (Baker, 2009). Change of use may bring about changes in purely technical parameters. Change of use may bring about an increase in the energy consumption. This does not necessarily mean that the low energy refurbishment has failed, since the measures adopted have undoubtedly led to lower energy consumption than if absent.

## 2.2. Legislation and strategies on energy efficiency in Kosovo

From the perspective of enabling energy efficiency in Kosovo, the following legislation and strategy documentation are important:

- *The Kosovo Law on Energy Efficiency* is compatible with EU legislation, specifically with reference to the Directives on energy efficiency for provision of necessary incentives and improvement of the energy efficiency in all consuming sectors (Directive 2004/8/EC, amending Directive 92/42/EEC, Directive 2002/91/EC)
- *Kosovo program for energy efficiency and renewable energy resources 2007-2009* provides the framework for the implementation of energy efficiency and renewable energy in Kosovo.
- *National Energy Efficiency Plan of Kosovo*, represents the first long-term energy efficiency plan which covers the period from 2008 till 2016, sets indicative target for energy saving for the period 2008-2016 (based on the article 4(1) of Directive 2006/32/EC).
- *Draft Law on energy performance of buildings* is oriented towards the promotion of improvements to the energy performance of buildings, taking into account outdoor climatic and local conditions, as well as indoor climate requirements and cost-effectiveness, in Kosovo.
- *Policies for increasing energy efficiency* are developed to increase the efficiency related to the entry into force of the Administrative Instruction on the Labelling of Energy Products, the introduction of excise tax for inefficient light bulbs, mandatory application of energy efficiency measures related to the issuance of the utilisation permit for buildings, the increase in the price of electricity higher than 8.0% and application of block tariffs.

Based on the knowledge from the review of literature and legislation, a list of challenges regarding energy efficiency in Kosovo are given below:

- Implementation of Energy Efficiency (EE) measures is not seen as a priority for the government, but EE is seen as only a legislative “must” to fulfil the gap, aiming EU membership.
- The EE is mainly seen, planned as concept to production of renewable energy perspective.
- The energy production relies on two coal power-plants that produces 97% of overall energy, in paradox that Kosovo is looking for new economic growth, increase opportunities, and enhance quality of life, arising from the development of the energy sector.
- Incomplete legal framework for energy efficiency in residential buildings.
- Incomplete technical regulation regarding energy efficiency and changes on existing regulation on thermal energy saving.
- Lack of human capacities and coordination between organizations at central and local level.
- Lack of environmental awareness campaigns, to change the approach and understanding of the importance of the necessary thermal energy savings in building sector.
- Lack of innovative financing models for energy efficiency investments in the building sector.

### 3. Methodology

The research is a qualitative and exploratory study. The analysis of the city of Prizren's current historic core district profile is given, together with the strategic documents on conservation/refurbishment, national legislation and strategy documentation on energy efficiency. The simulation analysis of the energy efficiency of the traditional case house is made, based on modelling in DesignBuilder Software, 2015. For obtaining a social impression of the project, a qualitative study was conducted with open-ended questions and 30 interviews with people of Prizren regarding traditional housing in core historic centre of Prizren, presenting the main stakeholder groups: i) inhabitants; ii) municipal officials, and iii) civil society representatives.

The main research questions are:

- Will improved energy efficiency in traditional housing contribute to a more sustainable solution in economic, social and physical/environmental aspect?
- Does the legislation in Kosovo support improvement of energy efficiency in traditional housing a development strategy?
- What do the key people of Prizren, think about energy improvement of traditional housing in Prizren/Kosovo as potential towards sustainable urban development of Kosovo cities?

The first hypothesis, based on the climate and envelope data, is *“A traditional Albanian house (such as house Mashkulli), is nowadays not energy efficient due to poor thermal properties, but the use of both passive and active strategies can improve the environmental and energy performance of the building.”*

The second hypothesis is: *“By improving energy efficiency in traditional housing in Kosovo/Prizren, a more sustainable solution would be reached in economic, social and physical/environmental aspect of development”.*

The research methodology is segmented in different phases. In the first phase, the literature review, based theories and best practices on economic, social and environmental impacts of refurbishment vs rebuild, improvement of energy efficiency in traditional housing, building performance, passive design, sustainable urban development and inner city rehabilitation are studied. During the second phase, legislation and strategy documents are reviewed on Energy Efficiency in Kosovo. In the empirical section, the research was divided in two phases BI and BII. B.I. phase is a simulation analyses of a traditional house on building performance in historical core district centre of Prizren (Mashkulli house). U-values of the elements were calculated assuming the thermal properties of the existing building. In B.II phase, a qualitative analysis was conducted, based on 30 in depth interviews. The main driver of these interviews was finding their opinion on the potentials towards sustainable urban development of Prizren by improving energy efficiency in traditional housing in core historic central district of Prizren.

The types of data being used as for this research are divided into two groups, theoretical and empirical sections. Data for theoretical section of the study is based on: Sustainable refurbishment, Strategies for low emission refurbishment, energy use in traditional housing, environmental comfort standards, and passive environmental strategies. Data for the empirical section of the study is based on the conservation

plan of the historic core Prizren city district; building detail design plan of the traditional case-Mashkulli house, and interviews.

## 4. Case study and results

### 4.1. Analysis on urban planning and architectural design of the neighbourhood/ traditional house-Mashkulli

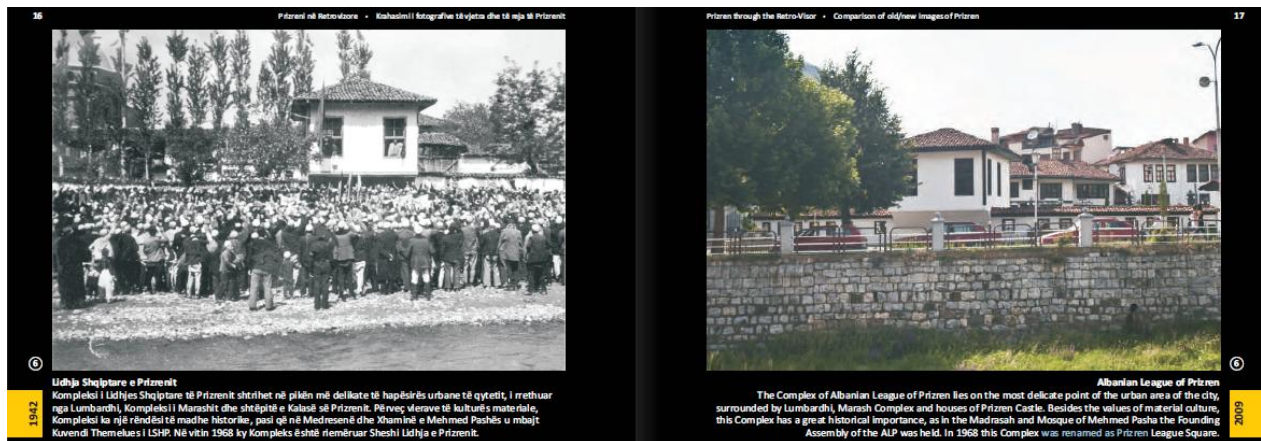


Figure 1: Before and after – neighbourhood of Mashkulli house (Source, EC ma NDRYSHE, 2012)

Prizren is famous city for its old, traditional dwellings. Starting from the Castle called Kalaja that dominates the city, the urban landscape is enriched with numerous historic buildings. Prizren has several urban residences. The diversity of the town's inhabitants, influencing each other in social and cultural terms, has had an impact on building and construction and the legacy of Byzantine and Ottoman culture during the 18th and 19th centuries is visible. Houses with a gallery are representative of the typical Albanian house, in comparison to other places in Balkans. It is surrounded by the National Park-Sharri Mountains, what influence on the climate, which is predominantly continental. Mediterranean climate also reaches Prizren due to Adriatic draught that comes through the river canyon.

Pilot project is a home of the Mashkulli family (Fig.1), an old building of the end of 18<sup>th</sup> century, in the centre of Prizren, near the Bajrakli Mosques and Medrese, nowadays known as the League of Prizren. By typology, the Mashkulli house belongs to the Urban House typology, accessed via main road parallel with the river Lumbardhi, entrance from the public square of "Prizren League", and then continue with private house garden, green zoning of the neighbourhood. The house is next to the landmark of the city, important node that defines character of a neighbourhood/city, under the conservation plan of the Prizren city (2005).



## 4.2. Energy Efficiency by simulation analysis – a case study

House Mashkulli is located in Prizren, in the southern part of Kosovo. It is a traditional Albanian house, mainly built from bricks (straw and soil mixture), where south/internal walls are made from stone. The floors and roof are insulated with soil between wooden boards, windows are single glazed with wooden frames. The U-values corresponding to the different envelope elements are calculated and summarised in table 2. This table also displays the required U-values according to passive house standards<sup>1</sup> for existing buildings and the amount of insulation needed to fulfil the requirements assuming the use of Rockwool 201 VARIO ( $\lambda = 0,034 \text{ W/mK}$ ). The windows need to be replaced.

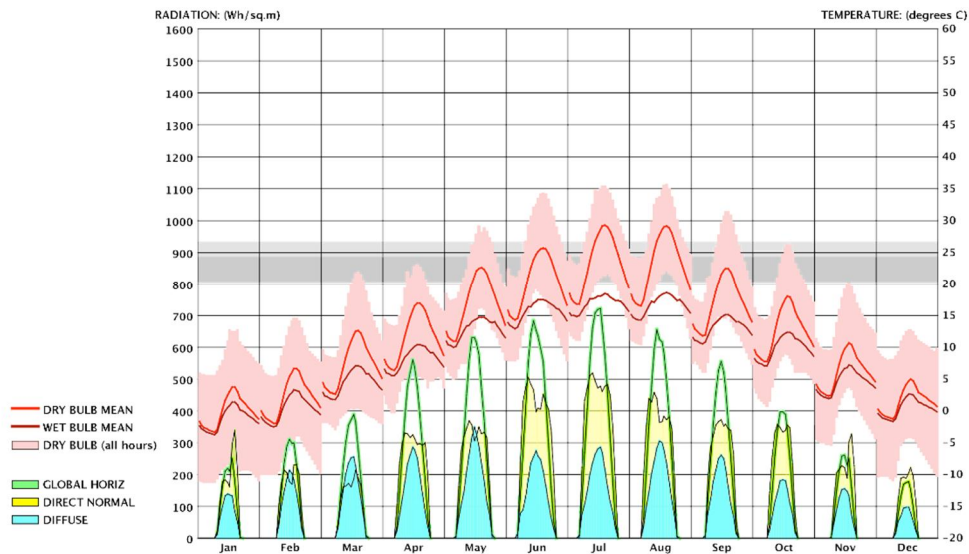
Element	Layers	thickness d [m]	thermal conductivity $\lambda$ [W/mK]	U-value [W/m <sup>2</sup> K]	PHS U-value [W/m <sup>2</sup> K]	Insulation needed [m]
Wall - brick	Int. surf. Resistance	0,01	0,7	0,98	0,15	0,19
	Lime mortar	0,16	0,2			
	Soil and straw bricks	0,01	0,8			
	Lime mortar	0,16	0,17			
	Ext. surf. Resistance					
Wall - brick, load bearing	Int. surf. Resistance	0,01	0,7	0,26	0,15	0,10
	Lime mortar	0,7	0,2			
	Soil and straw bricks	0,01	0,8			
	Lime mortar	0,7	0,17			
	Ext. surf. Resistance					
Wall - stone, load bearing	Int. surf. Resistance	0,01	0,7	2,52	0,15	0,21
	Lime mortar	0,7	3,5			
	Stone	0,01	0,8			
	Lime mortar					
	Ext. surf. Resistance					
Ground floor	Int. surf. Resistance	0,1	1,7	2,51	0,15	0,21
Floor	Ext. surf. Resistance			1,09	0,35	0,07
	Int. surf. Resistance	0,03	0,17			
	Wooden board	0,19	0,52			
	Soil filling	0,02	0,17			
	Ext. surf. Resistance					
Roof	Int. surf. Resistance	0,14	0,17	0,53	0,15	0,16
	Wooden construction	0,16	0,18			
	Soil and straw filling	0,02	1			
	Clay tiles					
	Ext. surf. Resistance					
Window	Single pane, wood			4,80	0,85	

Table 1:  
the existing  
U-values

overview of U-values of  
elements, the required  
according to passive

house standards, and the thickness of insulation that is needed to reach these standards.

Prizren has a maritime temperate climate classified as Cfb according to the Köppen-Geiger classification. The main challenge in a temperate climate is the seasonal variation between under-heated and over-heated periods (Figure 2.). This graph represents the monthly diurnal averages for Prizren with the comfortable temperature zones. Figure 3. shows the effect of passive strategies on the indoor comfort in Prizren for the whole year, the summer and the winter. The effective strategies vary with the season. The indoor temperatures are comfortable during 13% of the year. Over the whole year the effective strategies are solar shading, internal heat gains and passive solar gain. This results in 91,4% comfortable hours during the year and reduces the need for active heating systems to 45%. The hours that are not comfortable occur during the summer (8,6%), when the indoor temperature is higher. There are other passive strategies to make these overheated periods comfortable as well, but they will have only a small effect on the total (<5%) and are therefore not considered in this simulation.



Figure

## 2. Monthly diurnal averages for Prizren, extracted from Climate Consultant<sup>3</sup>

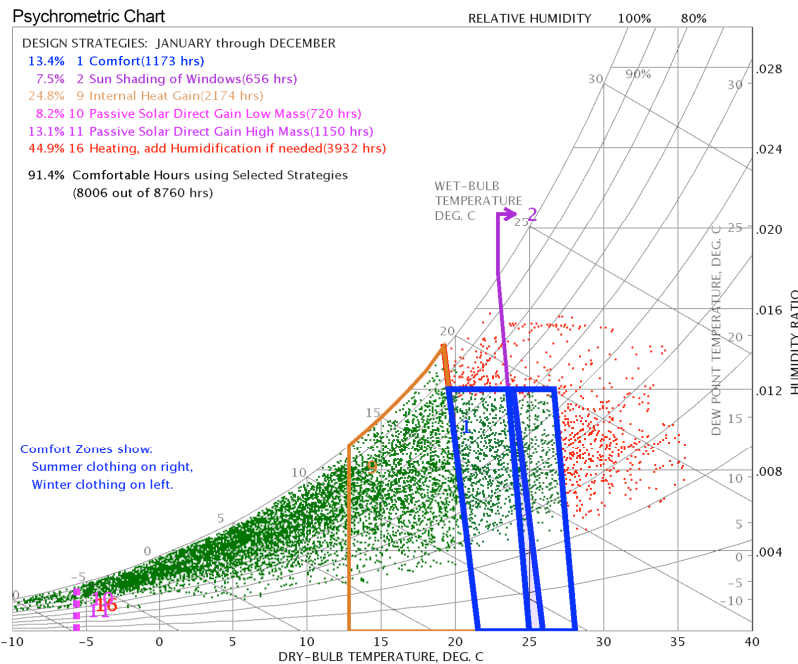


Figure 3:  
chart with  
passive

the indoor comfort (comfortable hours of the total in percent), extracted from Climate Consultant<sup>3</sup>

Psychrometric  
the effect of  
strategies on

In addition to these strategies, the shape and form of the building will also affect the energy consumption. A compact shape and no openings towards the north will result in less heat losses through the envelope. Openings towards the south can result in passive gain, but need to be shaded during the summertime to avoid overheating. Some of these strategies are already implemented in the Mashkulli house. The house has a compact design, is closed towards the north, uses thermal mass for solar storage, and has a light coloured building surface to avoid overheating in the summer. The building has a natural ventilation system, but the rooms mostly have openings in one facade, which makes cross ventilation possible only when doors between rooms are opened.

### 4.3. Research model and results

The building was modelled in Design Builder. U-values of the elements were calculated assuming the thermal properties of the existing building. The climate file used for the simulation was a weather file for Prizren. The building was divided into several zones (living room, hall, kitchen, bedroom), and both occupied and unoccupied zones were used in the simulation to be evaluated as one unit. The HVAC systems in the simulation were a cooling system powered by electricity and a heating system with biomass (wood). The house has no mechanical ventilation, but infiltration is high due to poor air tightness (1,5 ACH). The simulation time was one year, but only typical summer and winter week are shown in the graphs. In order to evaluate the environmental performance and energy efficiency of the house itself, simulations were made both with and without the active heating/cooling systems, for the existing and refurbished house with passive house standards. The HVAC systems were the same, but for the refurbished house, the mechanical ventilation was a fan coil system with 75% heat recovery.

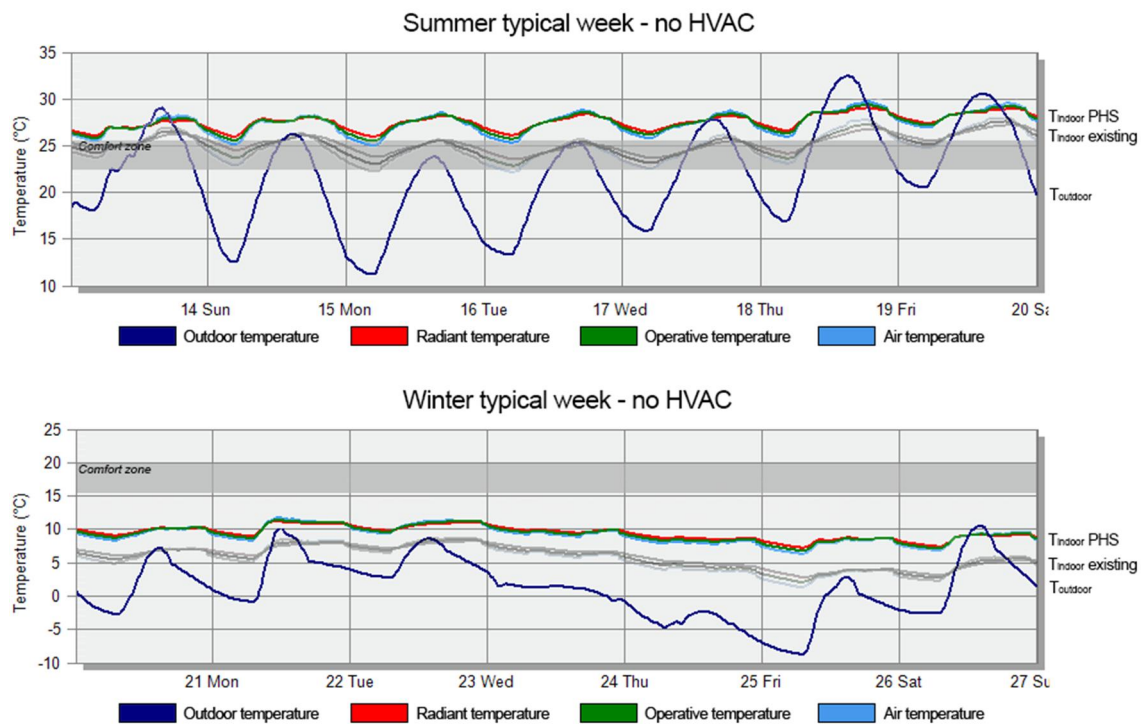


Figure 4: Indoor temperatures (no heating/cooling systems) for a summer and winter typical week

As seen (Fig. 4) that the temperature in the winter is much lower than the comfortable temperature in both cases when indoor temperature is simulated without any heating or cooling system. When passive house standards are applied, the indoor temperature rises throughout the whole year. In the summer it is visible that the indoor temperature can be higher than the comfort temperature, but on average the indoor temperature is within the comfortable temperature range in the existing situation. If the house is refurbished with passive house standards, the indoor temperature in the summer becomes too high and cooling is needed to retain a comfortable indoor climate. This shows that upgrading the house to passive standards is effective in the winter, but results in overheating during the summer.

When the indoor temperature of the house is simulated with active heating and cooling systems, it shows that indoor temperatures in the existing situation are still lower than the comfortable temperatures in the winter. The capacity of the heating system is not high enough to ensure a comfortable climate during the winter. The reason is in the high heat losses due to poor thermal properties of the envelope. When passive house standards are applied, the indoor temperatures are in the comfortable zone. During the summer in both cases the temperatures are lower with HVAC systems than compared to no systems, meaning that there are cooling systems active to lower the temperature in the house.

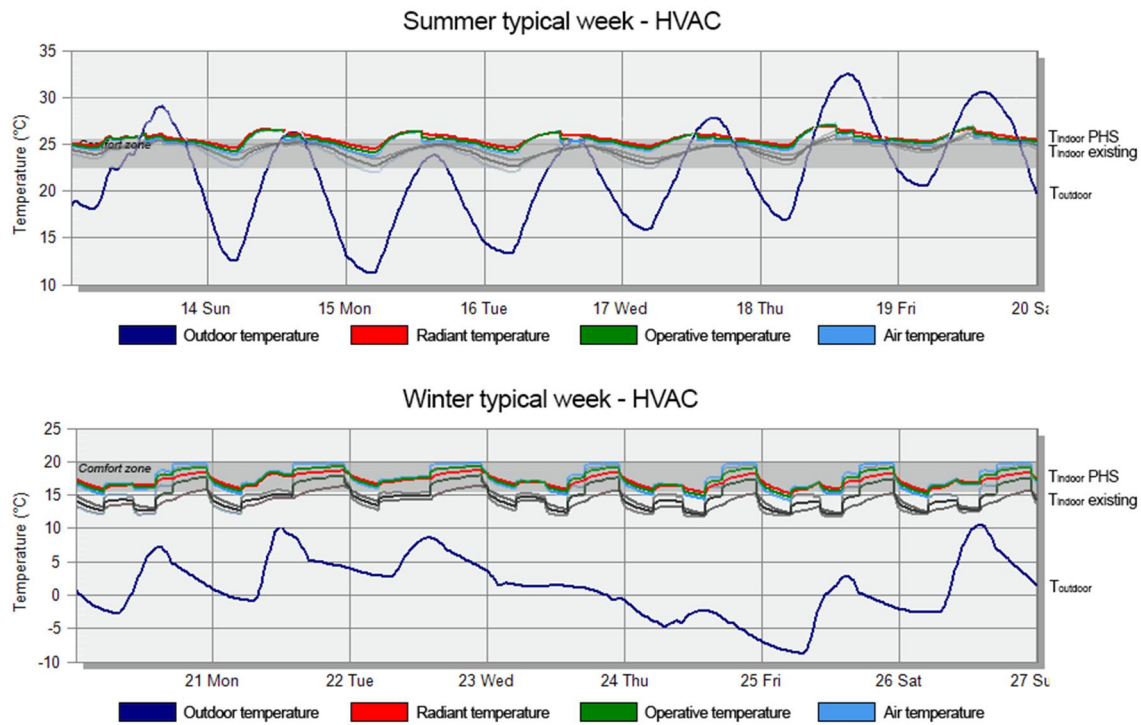


Figure 5: Indoor temperatures when heating and cooling systems are used in house Mashkulli for a summer and winter typical week

The total energy consumption of the house is 180 kWh/m<sup>2</sup> and the heating demand 140 kWh/m<sup>2</sup>. After refurbishment, the total energy consumption is 105 kWh/m<sup>2</sup> and the heating demand 62 kWh/m<sup>2</sup>. An improvement is 42% on the total energy consumption, and 55% on the heating demand.

#### 4.4. Interview analysis

In total 30 interviews were conducted with key people of Prizren regarding traditional housing in the core historic centre of Prizren and their needs, and the potential for sustainable refurbishment. The respondents were chosen from three focus groups: i) Inhabitants; ii) Municipal officials and iii) Civil society representatives (neighbours, owners of the craftsman shops, students and professors of architecture, ethnology researchers, NGO representatives, academic staff). In total, 27 open-ended questions are prepared. The perceived level of awareness/potential about three aspects of sustainable refurbishment: economic and social/cultural aspect, whereas environmental aspect seen as less important. The opinion of each target group regarding three sustainability aspects of refurbishment. The

most expressing warning and enthusiasm is civil society, meaning researchers, professionals, knowers of architectural values, whereas the most un not expressing the challenge were public officials.

## 5. Conclusions

From the A.I-Literature review, it can be concluded that refurbishment of traditional houses is more sustainable than rebuild or new built areas of housing, in many aspects such as cultural, societal, economic and therefore environmental. From A.II -Kosovo legislation and a strategic review of documents regarding Energy Efficiency in Kosovo, even though housing is considered to be as the biggest exploiter/user of energy, the policies for refurbishment/upgrading of housing are not seen as a priority for the state. Norms and standards aren't set as benchmarking for housing, although ways nor alternatives aren't set in practice (institutional, financial etc). From B.I phase, the simulation and the results show a potentially large decrease in total energy consumption (42%) and a decrease in the heating demand (55%) when the house is refurbished and more passive strategies are implemented. From B.II phase, the interview analyses, the results show that there is a room for improvement in the decision making institutions, taking refurbishment as one of the driving forces for energy efficiency.

From the research questions, it could be seen that those are approved: i) *'By improving energy efficiency in traditional housing would be reached sustainable solution in economic, social and physical/environmental aspect'*; ii) *'The key people of Prizren, think positively and do see energy improvement of traditional housing in Prizren/Kosovo as potential towards sustainable urban development of their city and of any city of traditional buildings'*; iii) *'Legislation in Kosovo does NOT support improvement of energy efficiency in traditional housing as solution and development strategy'*.

*The first hypothesis "A traditional Albanian house (such as house Mashkulli), is nowadays not energy efficient due to poor thermal properties, but the use of both passive and active strategies can improve the environmental and energy performance of the building."* has been approved. When the envelope of the house is refurbished to reach passive house standards and extra passive strategies are implemented, the total energy consumption of the house improves by 42% and the heating demand is reduced by almost 55% compared to the existing situation. However, the heating demand is still larger in comparison with passive house standards, so this house is not a passive one. *The second hypothesis* has been approved *"By improving energy efficiency in traditional housing in Kosovo/Prizren city, would be reached sustainable solution in economic, social and physical/environmental aspect of development"*. By improving the house, the environmental performance and energy efficiency of the house improves by implementing passive house strategies. In addition, these improvements will have an effect on multiple levels of sustainability, like the quality of life, because of better and more comfortable indoor climate (social), or on better impact of the environment, because it is more energy efficient (environmental), and on energy costs (economic).

International networking from research and development and using experiences to design traditional housing protection via energy efficient refurbishment measures could be beneficiary. The legal framework for EE in residential/traditional buildings, by settling of correlations in legislative framework within the area of energy, housing, spatial planning and building construction is needed.

New strategies for improvement and management in residential/traditional houses regarding energy efficiency followed by the appropriate raising awareness campaigns on thermal energy savings in building sector in general are necessary. Innovative financing in residential buildings through introduction of fiscal policy are needed for the application of customs relief connected with efficient technologies, subsidies on energy auditing costs, energy conservation investment costs and promotional activity costing.

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# A conceptual framework for sustainable retrofit project delivery for housing

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## Abstract

Some key factors are of prime importance in achieving the ambitious carbon reduction targets set by the European Union. In terms of greenhouse gas emissions, its aim is to achieve a 20% reduction on the 1990 levels by 2020 and an 80-95% reduction by 2050 compared to 1990. It has been established that building energy efficient houses and retrofitting the existing housing stock represent a sustainable way of tackling fuel poverty and increasing social and financial value. In seeking for ways to achieve this, a conceptual framework for ensuring the sustainability of building retrofit programmes was developed as part of this study. It considers sustainability as being driven by five environmental and economic priorities which include: reducing of carbon emissions, reducing energy bills and fuel poverty, increasing energy security, improving health and wellbeing and driving economic growth and creating jobs. However, a recent review of retrofit in the UK West Midlands Social Housing Organisations highlights that the most popular action for retrofitting in the region to date are: loft and cavity wall insulation; replacement of windows and doors; and the upgrade of heating systems. Most recent retrofit programmes, however, used external wall insulation or internal wall insulation where the former is not feasible. A questionnaire was sent to 24 RSLs in the UK West Midlands, some operating entirely within the area and some with stock in other parts of the country as well as the West Midlands. The developed framework provided a flowchart that caters for the integration of the key factors. It recommended that strategy and planning, housing stock data, funding, technical and delivery and tenant engagement are essential considerations in the development of sustainable retrofit solution. Future work will entail the development of the conceptual model into a full model to ensure that the sustainable solution it offers is properly articulated and validated.

**Keywords:** Building, retrofit, housing, energy, integration



# 1. Introduction

Increasing the energy efficiency and the energy performance of buildings will be key factors in achieving ambitious carbon reduction targets set by the European Union (EU Directive 2012/27/EU, 2012), (EU, “Directive 2010/31/EU”, 2010). In terms of greenhouse gas emissions, its aim is to achieve a 20% reduction on the 1990 levels by 2020 and an 80-95% reduction by 2050 compared to 1990 (EU Directive 2012/27/EU, 2012). Although the reduction of greenhouse gas emissions and the development of renewable energies are potentially achievable, it is likely to be very costly and difficult to carry out (Shorrocks et al, 2010).

In the context of carbon reduction, in many European countries, over the last years, there has been a significant concern in retrofitting of buildings in order to make the buildings more thermally efficient and sustainable (buildings are responsible for 40% of our energy consumption). Building energy efficient houses and retrofitting the existing housing stock represent a sustainable way of tackling fuel poverty, and, moreover, with increased social and financial value. This particular interest to building retrofit has been driven by five environmentally and economic priorities as: reducing of carbon emissions, reduce energy bills and fuel poverty, increase energy security, improve health and wellbeing, drive economic growth and create jobs.

The Report no 004 of the Centre for Low Carbon Futures highlights the importance of a rapid, policy driven transition to a low carbon economy in order to achieve mandatory carbon reduction targets. Retrofitting the buildings will take time, which is why this is a priority issue nowadays (Stafford et al 2011).

Generally, there are many pilot projects that aim towards a “nearly Zero Efficiency Building” (nZEB). This takes the “Passive House” standards incorporating a range of technology retrofitted. These include: draft proofing and floor insulation; water saving systems (fitting low volume baths, low flow taps and showers, dual flush WC’s); recycle and reuse water (rainwater and grey water harvesting, hot water) and heating systems (Air source heat pumps, ground source heat pumps, combined heat and power units, biomass boilers); upgrade of lighting system (LED lighting, light sensors, voltage optimization and renewable energies, photovoltaic and solar thermal panels, biomass and geothermal systems (Oloke, 2015).

A review of 73 pilot projects around 12 Countries in Europe was made and compared with UK retrofitting (Oloke, 2015). Countries compared were grouped according to climatic conditions, into: Mediterranean countries: France, Greece, Italy, Malta, Slovenia and Spain and non-Mediterranean countries: U.K, Bulgaria, Estonia, Sweden, Germany and Netherlands.

Similarly, the recent (2014) review of Retrofit in UK West Midlands Social Housing Organisations highlights that the most popular action for retrofitting in the region to date are: loft and cavity wall insulation; replacement of windows and doors; and upgrade of heating systems. Most recent retrofit programmes, however, used external wall insulation or internal wall insulation where the former is not feasible.



Generally, providers of social housing have the challenge of providing affordable energy efficient housing. Many tenants are likely to be fuel poor or in ill health and therefore would benefit greatly when the quality of accommodation is improved.

## **2. Background**

### **2.1 European Union and UK Framework on Energy Efficiency**

The objective of Directive 2012/27/EU on energy efficiency (hereinafter: EED) is to establish a common framework for promoting energy efficiency in the European Union. Article 4 mentions that Member States shall establish a long-term strategy for mobilising investment in the renovation of the national stock of residential and commercial buildings, both public and private (EU Directive 2012/27/EU, 2012). The European building stock is extremely diverse and could be differentiated between residential and non-residential use, both public and private. For the residential buildings, a distinction between single-family dwellings and multi-family dwellings is made.

A common form of multi-family dwellings are apartment blocks, usually maintained by a homeowner association (or condominiums or cooperatives of apartment owners). The residential buildings vary considerably from country to country (and from region to region), gathering a large variety of architectural and energy performance characteristics (which depend on the year of construction, building materials, or climate conditions). Depending on the climate conditions, Member States have to invest in energy efficiency differently, for warming or cooling the buildings (or both). Controlling the air temperature in indoor spaces and, in the same time, improving the energy performance of buildings, is a challenge.

The non-residential buildings have a variety of functions (administrative buildings, offices, schools, hospitals, commercial and industrial buildings, warehouses, etc). The uses of non-residential buildings are much more varied than the residential buildings, and therefore the energy use depends on the activities from these buildings.

The UK Government has placed special emphasis on the retrofitting and refurbishment of the UK's existing domestic and non-domestic buildings. It has committed to reducing greenhouse gas emissions by 80% in the year 2050 against 1990 levels. With about one quarter of emissions coming from domestic properties, the need to make reductions in this sector will be necessary to reach the target.

Residential Social Landlords (RSL)'s hold approximately 18 % of the UK housing stock (Fact File, 2013) and therefore a significant amount of the emissions relate to this sector. RSL's are motivated to increase the energy efficiency of their stock, to promote the health and well-being of their tenants, to provide tenants with financial resilience to increases in energy prices, to reduce greenhouse gas emissions and to provide resilience to the potential effects climate change. In a move to improve the quality of the UK housing stock, for example, the Government introduced the Decent Homes standard. RSL's have worked to make their own stock meet this standard and

are looking to increase the energy efficiency of their stock further and this continues to be a challenge across the continent.

## **2.2 Aims and Objectives**

In the light of the contextual background to this study, the paper aims to: propose a framework model for sustainable retrofit of housing stock. In doing this, the following objectives were achieved: a review the current position of Registered Social Landlords (RSL's) in the UK West Midlands with regard to the implementation of greenhouse gas emissions reduction in their housing stocks; and review innovative projects that demonstrate innovation in RSL's in order to exemplify the potential of success in the retrofit sector and propose a conceptual framework model for the recommendations of sustainable retrofit of houses.

## **3. Methodology**

Sequel to the review of existing literature, a questionnaire was devised to establish the progress UK RSL's have made to reduce greenhouse gas emissions. Based on the review of exemplars from other EU countries, the questions asked were concerned with strategies and plans that are in place to deal with energy efficiency within their housing stock, information about the energy efficiency of their housing stock, affiliation with bodies that give support in energy related matters, energy efficiency projects that have been delivered, funding and resources. The questionnaire was sent to 24 RSLs in the UK West Midlands, some operating entirely within the area and some with stock in other parts of the country as well as the West Midlands. 8 responses were completed and returned via email. 1 questionnaire was completed via a phone conversation and 1 face to face. Further to the collection of the data, analysis of the same facilitated the collation of the critical issues to be considered further and in the light of the objectives of this work to implement a framework.

Furthermore, in order to highlight the benefits of retrofitting to improve the energy performance of buildings, a range of best practice examples were analysed, compared to some European efforts and summarised. This is the basis for which a framework was proposed and recommendations for future development made.

## **4. Analysis of the Responses**

All the data collated were analysed under five themes. These were: strategy and planning, housing stock data, funding, technical and delivery and tenant engagement. The results in addition to an analysis of retrofit work replication potentials were subsequently used to develop a conceptual framework for the design and implementation of new retrofit scheme.

## **4.1 Strategy and Planning**

This examined the strategy put in place by an organisation to implement retrofit programmes and also the method used to plan and execute the programme. This aspect of the programme should ensure that the most effective project is proposed and designed. 9 of the 10 respondents confirmed having a strategy to tackle sustainability and environmental issues and have a plan to deliver energy efficiency measures. One organisation was in the process of developing their strategy as at the time of the survey. 2 of the respondents mentioned that they have strategies and plans that are reviewed on a regular basis. All of the respondents have roles within their business structure to support the planning and delivery of a strategy. Mostly this overall responsibility lies with one team within an organisation, although in one organisation the responsibility lay across two teams.

Policies regarding the environmental impacts of supply chain were found to be at different stages amongst the respondents. 4 organisations have a procurement procedure in place which included the environmental sustainability of the supply chain working with ISO 9001 and ISO 140001. 3 respondents use the Sustainable Homes Index for Tomorrow (SHIFT) benchmarking and road mapping process to deliver on this point, while the other respondents were currently developing policies.

## **4.2 Housing Stock Data**

The study further sought to interrogate the processes used to manage housing stock data. This helps to provide up-to-date information about the housing stock. 7 of the 10 respondents used a stock database system to manage record and plan energy efficiency measures. A number of databases were in use by the respondents including CROHM (Carbon Reduction Options for Housing Managers), Promaster In4systems, Active H MIS and Eco Homes XB. EPC's (Energy Performance Certificates) and DHS (Decent Homes Standard) were commonly used measure of energy performance. EPC's were commonly carried out during voids. Energy assessments varied from 50% to 100% of the total stock. Transferring EPC data to the stock database was mentioned as being problematic in one organisation. The potential to improve this process and allow an integration with other systems e.g. Building Information Modelling (BIM) is quite high.

## **4.3 Funding**

Several funding options had been considered. Carbon Emissions Reduction Target (CERT), Community Energy Saving Programme (CESP) and Energy Company Obligation (ECO) funding made a contribution to energy efficiency retrofit programmes for most organisations. One respondent was involved in a pilot project using funding from the Technology Strand Board. Other organisations have accessed EDRF (European Regional Development Funding) funding and Solutions 4 Energy. Many of the respondents were unclear what funding would be accessible in the nearer future. They indicated that the uncertainty in funding makes planning ahead difficult. One respondent gave two examples of projects that didn't proceed due to changes in funding at short notice. Another respondent acknowledged that where budgets showed a shortfall it was the 'non-essential' work such as the energy efficiency that would be cut. 7 respondents considered

ECO funding and 3 mentioned the Green Deal Home Improvement Fund. 2 respondents considered the Renewable Heat Incentive as a possibility whilst 1 respondent considered self-funded projects because of the uncertainty of funding. It was also another respondent's noted that the time frame for getting bids in is often too short and resources are not readily available to parachute into project. A consistent approach from the government to promote up skilling in the contractor was also thought to be necessary. Also, one respondent noted that the funding applications were overly complicated.

#### **4.4 Technical Delivery**

The RSL's mostly took the fabric first approach – a strategy which took advantage of current funding. Loft and cavity wall insulation has been the main stay of retrofit to date, along with replacement windows, doors and heating system upgrades. External wall insulation featured in many of the respondents more recent retrofit programmes. Some internal wall insulation had also been installed where external insulation is not feasible.

The range of technology retrofitted, in addition to cavity, loft and wall insulation, was however, very broad. The technologies included the following: fitting low volume baths, low flow taps and showers, dual flush WC's, grey water and rainwater harvesting, photovoltaics, solar thermal systems air source heat pumps, ground source heat pumps, combined heat and power units, biomass boilers, LED lighting, light sensors, voltage optimisation, draft proofing and floor insulation. Others measures not specifically energy efficiency measures include the provision of composting facilities, water butts and cycle storage facilities.

Whilst most of the work carried out had focused on energy efficiency, adaption work was under consideration by 6 of the 10 respondents. 4 of the respondents had carried out flood risk assessments. 1 respondent mentioned that they were intending to install ventilation systems in properties that were liable to overheating and another respondent installs mechanical ventilation in properties in the Extra Care scheme housing as they know that their tenants are more vulnerable.

One of the respondents said that they were aware of risks associated with the effects climate change, but considered that affordable warmth and fuel poverty were higher priority and this is where the focus lay at present. For projects involving renewable energy, 3 respondents reported using Feed in Tariff (FIT's) and/or the Renewable Heat Incentive (RHI).

In-house expertise and time was identified as resource that was missing from some organisations. An in-house technical specialist or consultant that could evaluate new technologies and funding that could provide advice throughout a programme. One respondent indicated the need for an on-site technical project manager, independent of the contractor.

The more innovative projects could be considered pilot projects and are being monitored and can be used to inform retrofit projects in the future. One organisation has found the installation of Combined Heat and Power units problematic as they are noisy and cumbersome. It has been

difficult to source replacement parts for the units. As the technology has moved on very quickly, the parts for older units have become obsolete. The performance of ground source heat pumps was found to be variable as that the system design is critical to this. 2 respondents have found that projects haven't delivered the expected savings. One organisation has discovered that the electric heating system hasn't provided the savings claimed by manufacturers, especially when residents are switched away from the Economy 7 tariff to more expensive daytime rates. One organisation commented that unexpected problems that occur during a project are not covered by the funding and are costly to the business.

## **4.5 Tenant Engagement**

Energy advice information is delivered in a variety of ways and different combinations of dissemination are used by the respondents. This included more general information on websites, through social media, newsletters and rent statement inserts. More targeted advice was given through home visits, coffee mornings, resident training courses and workshops. One respondent found that energy advice that is given peer to peer was well received following the training of some volunteer residents. Front line staff in one organisation was given access to e-learning and staffs attend resident's meetings to raise awareness. Another lends electricity monitors to their residents. One organisation noted that they have encountered difficulties getting residents involved in energy efficiency initiatives. Another respondent mentioned that advice given to tenants moving into retrofitted properties, where new technology were installed, was not consistent and was likely to dependent upon which officer was involved and whether written instructions are left with the tenant. Tenants that had air source heat pumps installed were found to need very specific instructions as the operating criteria were so very different from what they were used to.

Tenant involvement and understanding was considered by the respondents to be key in retrofit projects. One of the respondents commented that the transition is to be made easy for residents and show casing retrofits is essential.

## **5. Proposed Framework**

In the light of the foregoing, a conceptual framework is hereby proposed for the effective replication of retrofit projects. This will facilitate the implementation of efficient retrofit projects in the UK and across the EU (Bio Intelligence Service, 2013). Evidence suggests that coherent and well-designed schemes are exemplars that offer a very high potential of successful replication with the appropriate modifications and qualifications (Bosseboeuf, D, 2012). It was based on these concepts that a conceptual framework which incorporates the major strands of the outcomes of this research (See Figure 1). The process begins with an identification of the retrofits needs that pertain to a development and also an assessment of relevant successful exemplars (Oliveira et al, 2014; Chrobak et al, 2014). Many times these vary from property to property. However, a mass housing scheme would benefit from a scaled version of a particular programme. A strategy should thus be proposed if none exists and also the use of stock database management can ensue. This will entail the use of various database management systems that will facilitate improved

energy performance of the housing stock. These will lead to the estimation of resource requirements especially costs and the cash flow requirements. Depending on the funding available, the technical and delivery needs of each component of the scheme can then be assessed (Audenaert et al, 2014). For sustainability, the tenant engagement needs should also be assessed and incorporated into the programme of development in order to finalize the design and implementation of the new scheme. It is envisaged that future work on this development will include a testing of the proposed framework by Social Housing Providers. In doing so, specific issues and tools experienced can be incorporated using the evidence reviewed in this research and also those more specific to different schemes. Such work may also include the development of a more interactive toolkit that can be used as a decision support tools for the management of Social Housing Retrofit projects.

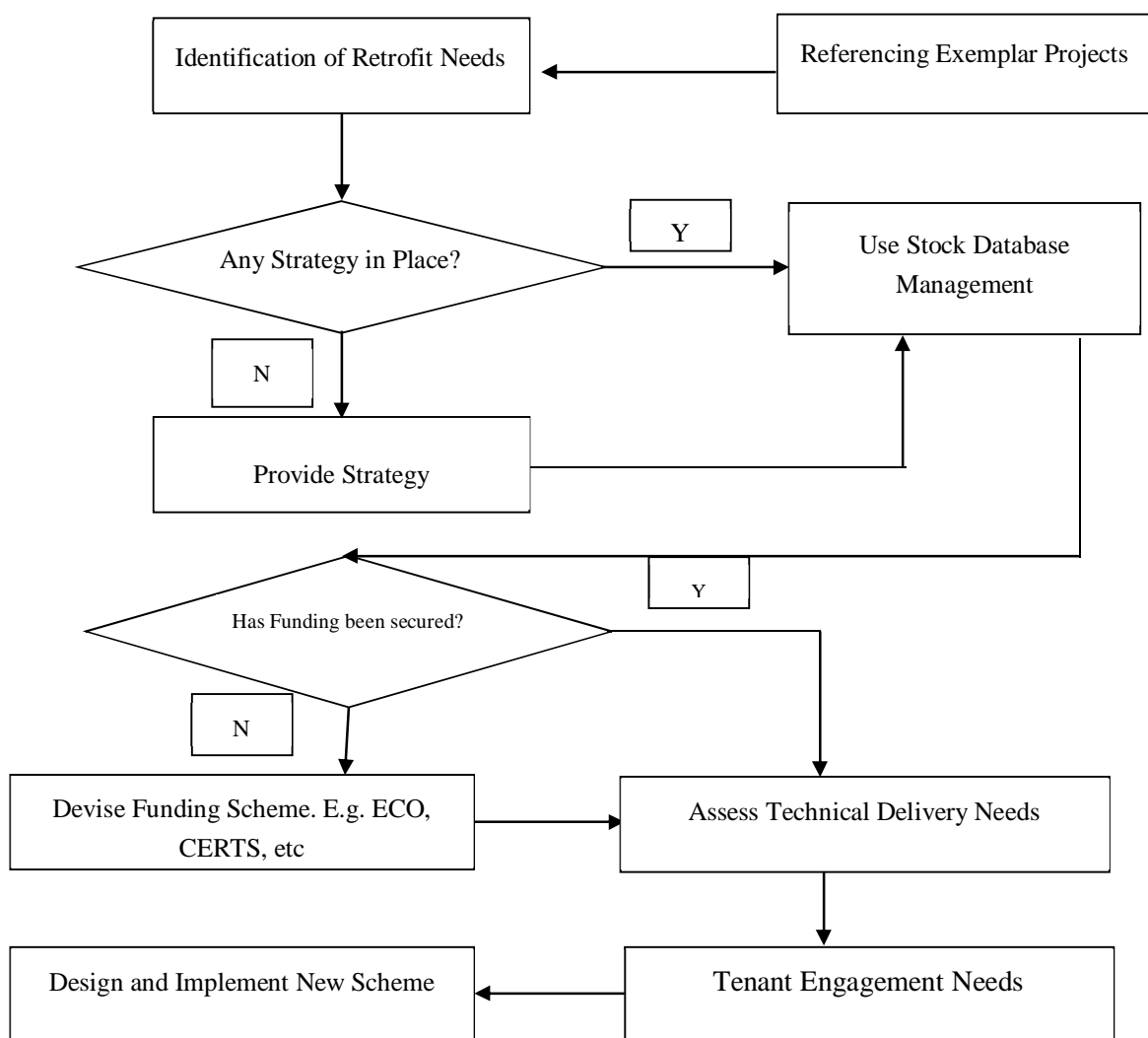


Figure 1: Proposed framework for the design and implementation of retrofit schemes

## 6. Conclusions and Recommendations

In many European countries, over the last few years, there has been a significant concern in retrofitting of buildings in order to make the buildings more thermally efficient and sustainable. Building energy efficient houses and retrofitting the existing housing stock represent a sustainable way of tackling fuel poverty, and, moreover, with increased social and financial value. To become sustainable, however, the economy has to be based on renewable energy and high resource efficiency and a sustainable approach to the retrofit of the buildings.

This paper aimed to: propose a framework model for sustainable retrofit of housing stock. The work entailed a review of the current position of Registered Social Landlords (RSL's) in the UK West Midlands with regard to the implementation of greenhouse gas emissions reduction in their housing stocks and subsequently presented the exemplification of the successes achieved so far in the retrofit sector after which the conceptual framework model sustainable retrofit of houses was proposed.

It was recommended that strategy and planning, housing stock data, funding, technical and delivery and tenant engagement are essential considerations in the development of sustainable retrofit solution. Future work will entail the development of the conceptual model into a fully - fledged model to ensure that the sustainable solution it offers is properly articulated and validated.

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# The effectiveness of the Last Planner System in New Zealand construction industry: Towards an empirical justification

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## Abstract

Productivity improvement has been a major initiative of the New Zealand construction industry. Currently the construction sector strives to increase productivity by 20% in 2020. Since 2009 an increasing number of construction organisations have implemented lean construction practices in an attempt to improve their project delivery. These lean practitioners have implemented the Last Planner System (LPS) as a production planning and control system to achieve project goals. Most LPS users have reported satisfactory results from their implementation, however, there is a need to provide empirical support to these claims. This study investigates the usefulness of LPS implementation amongst construction industry users in New Zealand. It determines from the study the level of LPS implementation and provides empirical evidence of the benefits of its implementation in New Zealand. A survey of practitioners' viewpoints is collated using an online survey portal. The data is analysed descriptively and quantitatively to provide empirical evidence of LPS benefits. The study finds that there are some few challenges needed to be overcome within construction organisations before fuller benefits of LPS can be realised.

**Keywords:** Construction productivity, Last planner system, New Zealand

# 1. Introduction

There are performance issues connected with the execution of construction projects. Most of the issues are practical requiring deeper understanding as we seek solutions to them (Love, Holt & Li, 202; Wing, Raftery & Walker, 1998). Management of projects in the construction industry can be challenging due to the complex and fragmented character of the industry. Furthermore, poor project management is suggested by Alsehami, Tzortzopoulos, & Koskela (2009) as a contributory factor to construction project performance issues. Therefore innovative management approaches have become essential to mitigating construction performance challenges. Subsequently an approach that is commonly described in literature is the use of Lean construction. Other management and research efforts have been suboptimal and tend to be descriptive and explanatory (Koskela, 2008), rather than being practical.

Therefore, central to project performance is the concept of lean construction. Lean construction is a new paradigm that has evolved in response to challenges experienced in traditional management approaches. Within this paradigm, the Last Planner System (LPS) emerged as a tool with special focus on reducing the negative impacts of variability and increasing reliability of workflow for production planning and control (Alarcón & Cruz, 1997; Ballard, Hamzeh, & Tommelein, 2007; Ballard & Howell, 1994; Ballard & Howell, 2003; González, Alarcón, & Mundaca, 2008).

Review of related studies show that in the last decade, construction industries around the world have endeavoured to implement Lean Construction principles and the LPS on their projects. There have been studies using experimental, action research, and empirical methodologies to determine the implementation of LPS and other lean techniques in various perspectives. Examples are studies that assess the effectiveness of the new paradigm (Alarcón, Diethelm, Rojo, & Calderon, 2005), develop strategies and support tools (Alarcón et al., 2005), improve construction performance (Alarcón et al., 2005), and adopt new improvement approaches to the construction sector (Bertelsen, 2002; Hamzeh, 2009). However there is little evidence of the practical implementation of the LPS in New Zealand and of its effectiveness in addressing construction industry problems. Therefore, the current study addresses this knowledge gap by providing empirical justification of the implementation of LPS. The main objective of the study is to determine how LPS has been used among NZ construction organizations toward supporting the current initiatives for 20% increase in productivity by 2020 in New Zealand.

To pursue this objective, an online survey was administered to LPS users in New Zealand and the results analysed. The study provides some empirical justification for the use and implementation of LPS amongst construction organisations in New Zealand.

## 2. Historical background to Lean Construction and Last Planner System

Measuring productivity and performance issues, enable Managers to identify where and how improvement approaches should be applied in projects. Performance measurement is vital to

project management as it addresses a wide range of project management aspects including improving management and control, enhancing middle management functionality, reducing urgent procurement requests, and shrinking project schedules (Alarcón et al., 2005). However accurate measurement of performance by construction organisations is challenging. Quantitative and qualitative methods using performance indicators such as man-power productivity, cost factors, construction speed, and schedule reduction are reported in Alarcón et al. (2005). Value realisation is a significant measure of performance, as suggested by Ballard and Howell (2004), wherein value is provided when customers are enabled to accomplish their purposes for executing projects.

The seminal work of Ballard (1994); Ballard and Howell (1994); Howell and Ballard (1994a, 1994b), have advanced knowledge on work performance within construction projects. Their studies of workflow variability and measuring its variation in the form of plan failure rate on weekly work plan's assignment have been commended. The study results reveal that most construction plan failures are within contractors' control. Workflow variability was found to be persistent and routine rather being spasmodic and small.

Furthermore, Green, Fernie, and Weller (2005); Hopp and Spearman (2008); Spearman and Hopp (1996); Vrijhoef and Koskela (2000) have observed that most performance issues in the construction industry are the consequences of entrenched traditional practices (i.e. myopic view of project parties, high levels of various forms of wastes, low levels of trust, lack of communication and transparency, low customer satisfaction, and high variability). Hence the need for a lean construction approach that advocates collaborative production planning and execution with emphasis on workflow reliability, maximising value for customers, and minimising waste (Ballard & Howell, 1998).

As a major tool in lean construction, the LPS was developed as a tool for the management of construction processes, and continuous monitoring of its planning efficiency (Alsehaime et al., 2009). The LPS was introduced by Ballard (1993) to members of IGLC-1 (1st meeting of the International Group for Lean Construction). The principles of the LPS were developed at IGLC-2 in 1994 (Ballard, 1994), and further elaborated at IGLC-5 in 1997 (Ballard, 1997). By IGLC-5, the LPS was complete and ready to be introduced broadly (Bertelsen & Nielsen, 1997). The LPS is composed of some integrated components such as the master plan, phase plan, lookahead plan, weekly plan, and planned percent complete (PPC) determination. The adherents of LPS claim that systematic implementation of LPS can bring many advantages and increase benefits to both construction management practice and planning practice (Alsehaime et al., 2009). Thus LPS has become synonymous to lean construction practice to improve construction projects' performance. More detailed description of the LPS is provided in the following subheadings.

## **2.1 Last Planner System (LPS)**

As earlier indicated the LPS is a production planning and control tool developed based on Lean principles (Kim, 2014). The general objective of lean principles is to support management through the reduction of performance variabilities, enhanced reliability, and continuous monitoring and

improvement of project performance. LPS ensures constant stabilisation of workflow and improves productivity (Christoffersen, Sander & Bojsen Jensen, 2001; Hamzeh & Langerud 2011).

It has been suggested that growth in project planning software caused the loss of short term planning for construction projects (Harris & McCaffer, 2006). LPS was developed to address reliability issues at the weekly work plan level, while aiming to cover full planning and schedule development complementary to Master Schedules. Main components of the LPS are: Master plan, Phase planning, Lookahead planning, and Weekly work plan (Mossman, 2009; Koskela, Stratton, & Koskenvesa, 2010). Recent research suggested another phase to the LPS structure: 'Learning', that measures PPC, analyses root causes for non-completions and develops the lessons learned to successfully re-engage incomplete tasks (The Last Planner, 2013)

LPS implementation have been the subject of several studies. Alarcón et al. (2005) studied the implementation of LPS and other lean techniques in over 100 construction projects (between 2000 and 2005). The issues investigated include: 1/ improvements in percent of planned assignment completed, 2/ influence on the level of implementation on project PPC, 3/ Causes for non-completion in projects, 4/ variability of PPC measures, 5/ the impact of IT support on PPC performance, 6/ performance improvements, and 7/ implementation barriers. The findings from Alarcón et al. (2005) study have been used to develop an implementation strategy which includes development of systematic training and research action, proactive interaction between key project organisations, collaboration among companies and a constant search for new ways to improve LPS implementation. Projects may implement LPS in different levels according to the elements of LPS: 1/ at a basic level, LPS can be implemented with emphasis on the weekly work plan and informal Lookahead planning process, and 2/ implementing the LPS using formal Lookahead planning processes. Alarcón et al. (2005) found another situation where formal workable backlog and learning processes had been used in the implementation of LPS. A likely conclusion is that each level of implementation brings about different benefits to projects.

Kim (2014) suggests various benefits attributable to LPS implementation on construction projects. A shortlist would include: 1/ identifying the main reasons for project variances (incomplete prerequisite work, bad planning, and design issues), 2/ achieving continuous improvement through PPC measurement, 3/ successful completion of projects through weekly pull-planning by project teams, and 4/ mitigating problems originated by the project structure. Further benefits include: 1/ realisability of promises which team member made to each other and to the project, 2/ identification of the causes of broken promises and variances through weekly work plan analysis, and 3/ avoidance of repetitive project shortcomings.

In spite of the benefits outlined above, LPS implementation seems suboptimal in different countries and in respective organisations. Alarcón, Diethelm and Rojo (2002) and Alarcón et al. (2005) had identified some barriers to the full implementation of LPS in organisations. These include: 1/ low understanding of the concept of LPS, 2/ low utilisation of the different elements of LPS, 3/ inadequate administration of the necessary information to generate a "learning cycle" and to take corrective actions, 4/ weak communication and transparency among practitioners, and

5/ lack of integration of the production chain. Porwal, Fernández-Solís, Lavy and Rybkowski (2010) have also suggested implementation challenges at industry-level which inhibit the adoption of LPS in industry.

There is evidence to suggest culturally-based factors impact LPS implementation (Alsehaimi et al., 2009). According to Alsehaimi et al, lengthy approval processes by client organisations due to bureaucracy, poor commitment and attitude to timeliness, were unique to Middle Eastern countries. In New Zealand, Fuemana, Puolitaiva and Davies (2013), conclude that the low uptake of LPS across all project types impacts on the full realisation of its benefits. Fuemana et al. (2013) indicate that collaboration amongst project participants underlies productive goals realisable from LPS implementation. They went further to recommend the adoption of other Lean methods and integrated procurement methods to the New Zealand construction industry, as a way of improving collaborative workings.

### **3. Study Approach**

To investigate the effectiveness of the LPS within the construction industry in New Zealand, the study first identified LPS practitioners from information held by Constructing Excellence in New Zealand (<http://www.constructing.co.nz/>). Lean construction had been offered to the NZ construction industry since 2009, and awareness of LPS as a production planning and control tool is gaining good traction. Although, most of the LPS users have reported satisfactory results, there is a need to provide empirical support to these claims. To do this, the study collected the required data through an online survey (survey monkey) administered to LPS practitioners in New Zealand. The survey contain five (5) key sections including: Demographic information, status of LPS in New Zealand, LPS effectiveness within organisations, barriers to LPS implementation, and benefits of LPS to construction projects. The questions asked were generally in the form of scales, rankings, and open ended types to provide responses used for the analyses. An outline of the demographic information collected for this study is explained in the following paragraph.

There were several related questions covering: job position, years of construction experience and years of professional experience in LPS methodology. The question on job position gives an overview of the role of the study participants. The purpose of the question is to know the background of the participants, which will allow further understanding of the nature of their responses. The results clearly indicates that majority of the participants (66.7%) operate at project management level while 11% are field supervisors. A total of 22% of the participants indicated that they hold other positions that were not listed in the questionnaire. Another question within the demography section relates to the years of construction experience of the participants. The result shows that significant percentage (70%) of the participants have over ten years of construction project experience with only 10% indicating between five to ten years. 20% of the participants have between two to five years of work experience. It is important to note that none of the participants had less than two years of experience within the construction industry.

Participants were further asked to indicate their years of professional experience in LPS practice. Majority of the participants (80%) have between two to five years of experience in the use and implementation of LPS within their organisations. An equal number of participants (10%) have between zero to two years and five to ten years respectively. Comparing these two questions on construction experience and professional experience in LPS practice, it is reasonable to conclude that while most people had a high level of experience in construction project management, lower numbers had good levels of experience on the use of LPS. This is not unusual considering that LPS has only been introduced into New Zealand fairly recently.

The demographic information summarised above suggests that the survey covered the population targeted for the study. The results appear to show that the participants selected for this study are reliable for the investigation of the effectiveness of LPS within the construction industry in New Zealand.

The results of the survey are presented in the next section using simple interpretive and descriptive methods. This is desired to provide an easy read, be more understandable and communicative.

## **4. Results and Discussion**

### **4.1 LPS status in New Zealand**

A summary of the status of LPS implementation in New Zealand is obtained from study participants is tabulated (see Table 1). The information shows that a significant percentage (33%) have only recently implemented LPS on their projects. Generally practitioners received both external and internal support in the form of: training course, workshops and periodic meetings on the use of the LPS. There is the general consensus that the support received had positively influenced implementation of LPS. Although responding to the level of popularity of LPS within the construction industry, 58% of study participants had indicated that LPS is not yet widespread.

A significant percentage (29%) of study participants had implemented LPS on projects worth over \$100 Million followed by 14% on projects worth between \$5-20 Million. More than 50% of study participants have applied LPS in all of their projects regardless of the size of the projects (see table 3). Furthermore the survey results show that LPS was mostly implemented during the construction phase (75%) compared to other phases such as: project definition, design, and prefabrication. Primavera is the most common software used for preparing and presenting master schedules by the study participants, while MS Excel was preferred for preparing and presenting weekly schedules. As is observed from Table 1, Primavera, MS Project and MS Excel were used in preparing and presenting Lookahead schedules.

*Table 1: Summary of LPS status*

<i>Demographic Questions</i>	<i>Answer Options</i>	<i>Response Percent</i>	<i>Response Count</i>
<i>How long ago did your organisation begin implementing the last planner system (LPS)?</i>	<i>1 yr</i>	<i>8.3%</i>	<i>1</i>
	<i>2 yrs</i>	<i>33.3%</i>	<i>4</i>
	<i>3 yrs</i>	<i>16.7%</i>	<i>2</i>
	<i>4 yrs</i>	<i>25.0%</i>	<i>3</i>
	<i>Over 5 yrs</i>	<i>16.7%</i>	<i>2</i>
<i>How much do you feel LPS implementation is widespread within the NZ construction industry?</i>	<i>Poor</i>	<i>16.7%</i>	<i>2</i>
	<i>Below average</i>	<i>58.3%</i>	<i>7</i>
	<i>Average</i>	<i>25.0%</i>	<i>3</i>
	<i>Above Average</i>	<i>0.0%</i>	<i>0</i>
	<i>Excellent</i>	<i>0.0%</i>	<i>0</i>
<i>On what scale of construction projects do you feel the LPS can be best implemented?</i>	<i>Below \$5Million</i>	<i>0.0%</i>	<i>0</i>
	<i>\$5 - 20 Million</i>	<i>0.0%</i>	<i>0</i>
	<i>\$20 - 100 Million</i>	<i>0.0%</i>	<i>0</i>
	<i>Over \$100 Million</i>	<i>0.0%</i>	<i>0</i>
	<i>All Projects</i>	<i>100.0%</i>	<i>12</i>
<i>At what phase of construction projects do you normally implement LPS in your organisation?</i>	<i>Project definition</i>	<i>0.0%</i>	<i>0</i>
	<i>Design</i>	<i>16.7%</i>	<i>2</i>
	<i>Prefabrication</i>	<i>8.3%</i>	<i>1</i>
	<i>Construction</i>	<i>75.0%</i>	<i>9</i>
<i>Software used for the following:</i>	<i>MS Project</i>	<i>Primavera</i>	<i>MS Excel</i>
<i>Preparing and presenting the master schedule (n=11)</i>	<i>3</i>	<i>5</i>	<i>4</i>
<i>For preparing and presenting the Lookahead schedule (n=11)</i>	<i>3</i>	<i>3</i>	<i>8</i>
<i>For preparing and presenting the weekly schedule (n=11)</i>	<i>1</i>	<i>2</i>	<i>10</i>

## 4.2 LPS Implementation on projects

To determine the main driver for LPS implementation on construction projects in New Zealand, study participants were required to indicate amongst a set of drivers, what had been their objective for implementing LPS. The result is tabulated in Table 2 and it shows that the major driver (100% response) for LPS implementation was the need for proper time management and controlling delays, followed by ‘reducing process/production waste’ etc. The result show that project owners had no influence on the implementation of LPS in projects in New Zealand.

Table 2: Main drivers of LPS implementation

S/No	Drivers (re-ordered)	No. of Responses	Percentage Response
1	Proper time management & controlling delays	12	100
2	Reducing process/production waste	10	83
3	Safety improvement and control	7	58
4	To be ahead of industry on the use of LPS	3	25
5	To be responsive to industry trends	1	8.5
6	In response to Client requirements	0	0

The study participants were required to rate the effectiveness of the LPS on their projects. Most of the participants had rated effectiveness of the LPS as above average and excellent, 73% and 27% respectively. This result would suggest that LPS would influence PPC on their respective projects. Considering that Alarcon et al (2005) had found significant relationship between LPS implementation and planned project completion rates (PPC).

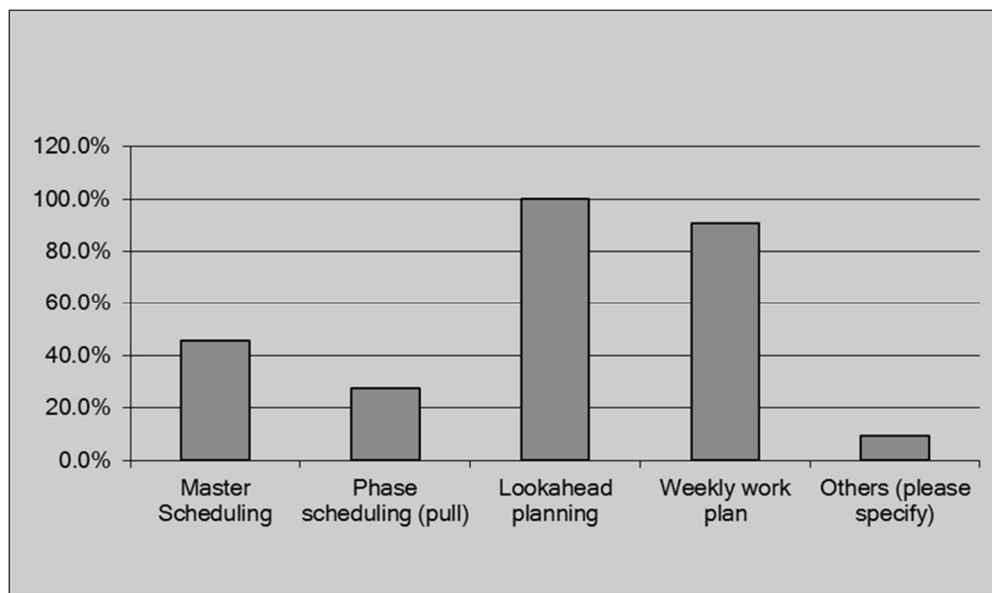


Figure 1. Components of LPS included in planning processes

Furthermore, to identify how New Zealand uses the LPS, study participants were asked to specify which component(s) of LPS is/are included in their planning processes. With this, the level of importance of the components would be identified. The responses are presented in bar chart form in Figure 1. Generally all the components of the LPS are included in their planning processes. However 'phase scheduling' was the least ranked (27%) in spite of its primacy in LPS implementation. Phase scheduling is vital to projects as it can assure the completion of the right work at the right time, and consequently the achievement of project goals (Ballard 2000b). Phase scheduling divides up the master plan into various phases toward developing more detailed work



plans and providing the project team with more clear goals. Therefore phase scheduling is the bridge between master plans and Lookahead plans.

To gain a better understanding of the use of phase scheduling, participants were asked to indicate at which project phase it was applied. The study found that phase scheduling was used mostly at the structure phase (67%), followed by more than 50% during foundation and design phases, and 25% to 33% at project definition and closeout phases respectively.

Another section of the survey was designed to ascertain how Lookahead plans were developed during LPS implementation. Lookahead planning allows the breakdown of project activities into operational levels, where constraints are identified, responsibilities assigned and tasks made ready. 73% of the study participants indicated that their Lookahead plans were developed by breaking down master schedule activities. As opposed to 18% that use the phase schedule activities directly. Further, the study participants indicated that Superintendents, Project Engineers, Foremen and Project Managers (in that order) were responsible for the preparation of Lookahead schedules. As noted by Laufer and Tucker (1988), the extent and manner in which users were involved in LPS decision making process can affect the success of the implementation of the tool. The results of the current study would suggest that the level of participation of project participants is adequate in LPS implementation.

Finally, study participants were required to indicate the level of communication and integration that exists within their current project partnerships. The results indicate that the level of communication and transparency among participants vary from average to above average, where communication was ranked above average by 73% of LPS users. The level of integration among project participant was rated similarly from average to above average, 63%, and 27% respectively. Another aspect of the survey desired to determine to what extent knowledge sharing and communication benefitted LPS implementation among New Zealand users. The results showed that 36% of the participants are in strong agreement that knowledge sharing can improve LPS implementation, where 45% are agree and less than 10% are strongly disagree.

Collaboration and active participation of multiple parties is key for the successful implementation of project plans (Laufer & Tucker, 1988). Chinowsky, Diekmann, and Galotti (2008) argue that the management of projects could be considered as the management of social collaborations. Chinowsky et al. (2008) shows through a developed social network model, the importance of communication among project networks, and that through the clarification of roles, high performance results could be realised on projects. Recognition of individual roles through active communication and trust provides individuals with more knowledge of each other's needs and constraints. Consequently, project teams become more knowledgeable and in a position to deliver better performance over time. Collaboration of individuals is a vital part of LPS implementation that differentiates it from traditional planning methods.

## 5. Conclusions

The objective of the current study was to investigate the effectiveness of the LPS within the construction industry in New Zealand. The study had used a survey instrument administered online to elicit response from LPS practitioners in New Zealand. The results obtained were analysed simply, to provide some empirical justification of progresses made in LPS adoption as a planning and control tool for projects.

The study found a good level of implementation of the LPS in New Zealand. The main components and constituents of LPS as a planning tool are understood and applied by a significant proportion of practitioners. There are reasons to suggest from the views presented that the benefits for LPS implementation are being realised on construction projects. Project participants are aware of their roles and responsibilities towards LPS adoption and a good level of collaboration exist between project participants. It is therefore safe to conclude in the current study, that LPS implementation have been effective amongst practitioners in New Zealand.

Towards more empirical investigations the study suggests that performance data (e.g. PPC) could be obtained from LPS practitioners. This was a limitation of the current study. Also it would be useful to collect information from project owners for whom ultimate benefits are expected. Information on how well their project deliverables were achieved using LPS practitioners as compared to other projects may provide further evidence of the effectiveness of the LPS tool.

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# Improving Transition from Engineering to Construction Using a Project Execution Model and BIM

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## Abstract

Usually engineering takes place during a given time period, followed by construction. Shorter time from project start-up to delivery gives higher parallelism between project phases. Construction pushed in parallel with engineering places greater demands on the actors. Parallelism calls for increased interaction between engineering and construction. This paper assesses how transition from engineering to construction can be improved with the use of a project execution model (PEM) and utilization of building information models (BIM). Findings are presented in three interdependent dimensions; process, people and technology. Research is based on case studies of major oil and gas projects, where data is gathered through Kvaerner, a Norwegian EPC (engineering, procurement and construction) contractor. Primary focus is on EPC contracts, where engineering and procurement is subcontracted, which corresponds to design-build contracts in the construction industry. The EPC contractor will build in a sequence that is cost effective for them, while the engineering subcontractor prefers to think in a totality until engineering is finished. Parallelism challenge this. To improve transition, it is important with a correlation between how one conducts engineering and how one plan to build. How can deliveries from the engineering subcontractor be produced in an order that fits into the desired build sequence to the contractor? The paper portrays how an alternative contract model is used, how common drivers are established and how the use of a 3D design environment, which corresponds to BIM in the construction industry, is rearranged to support this. "Right the first time" is when a certain quality level is achieved to a certain point in time. Using a PEM supports this by defining requirements on each milestone that must be achieved to reach the desired quality level. If some disciplines are behind and some ahead of a milestone, it will not be "right the first time". How can the engineering subcontractor satisfy milestone requirements to the contractor and deliver "right the first time"? The paper shows how the engineering subcontractor, with certain additions and adjustments to their milestones, can support this. The integrated design and delivery solutions (IDDS) approach relate the findings towards the construction industry.

**Keywords:** building information model, build sequence, joint venture, milestone requirements, project execution model

# 1. Introduction

In current practice, engineering and construction phases are not well integrated (Luth et al., 2013), and usually engineering takes place at given period of time, followed by construction. In offshore projects, executed at EPC (engineering, procurement and construction) contracts, construction is often pushed in parallel with engineering. EPC contracts corresponds to design-build contracts in the construction industry, where the engineering and construction are contracted by a single contractor. Influence and inclusion of contractors in engineering in design-build contracts is important since contractors can receive deliveries based on their expertise in buildings solutions (Berard and Karlshoej, 2012). This involves grouping activities into work packages so that construction can start before the design phase is complete (Bogus et al., 2011). To improve transition, it is important that there is a correlation between how one conducts engineering and how one plan to build. When working in parallel, the contractor starts at a certain place and build, and that is the place engineering should have drawings and materials first. The paper assesses how deliveries from the engineering subcontractor can be produced in an order that fits into the desired build sequence to the contractor. This can be fulfilled using a project execution model<sup>1</sup> (PEM), an alternative contract model, common drivers for the project team, together with an altered structure of a 3D design environment<sup>2</sup>. A 3D design environment corresponds to a building information model<sup>3</sup> (BIM) in the construction industry. The paper investigates how the engineering subcontractor can satisfy the milestone requirements to the contractor and deliver “right the first time”. The engineering subcontractor can accomplish this by adjusting their milestone requirements in the design phase. Primary focus is on EPC contracts, where engineering and procurement is subcontracted.

The findings in this paper are divided into three interdependent dimensions; process, people and technology. Process, people and technology are identified as core organizational issues (Sacks et al., 2010) or categories used to classify challenges and benefits in an integrated design process (Rekola et al., 2010). To succeed requires a holistic approach, where all three dimensions are mutual dependent of each other. The first part, process, looks closer at parallelism in EPC contracts and how an engineering subcontractor can support this by adapting to a desired build sequence to the EPC contractor. This requires “right the first time” deliveries, with right information at the right time, and milestone coordination between the engineering subcontractor and EPC contractor. To accomplish this requires focus on the second dimension, people, which identifies common incentives and drivers. This includes the possibilities of establishing a joint

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<sup>1</sup> A project execution model (PEM) reflects a logic sequence in critical project activities where progress and quality requirements are aligned at significant milestones. The objective of a PEM is to secure predictability in project execution using a standard methodology well known to the team Kvaerner, 2012b).

<sup>2</sup> A 3D design environment refers to a multi-discipline and object based 3D design integrated with a number of information systems that serves as the main source of information for engineering and construction (Kvaerner, 2012a).

<sup>3</sup> A building information model (BIM) can be defined as a digital representation of physical and functional characteristics of a facility, and a shared knowledge resource for information about a facility that forms a reliable basis for decisions during its life cycle (NBIMS, 2007) .

venture between the engineering subcontractor and EPC contractor, identify drivers to secure alignment to common goals and mobilize new project teams. This also requires focus on the last dimension, technology, which investigates how a 3D design environment (hereafter called BIM) can be utilized to support a desired build sequence to the EPC contractor.

The integrated design and delivery solutions (IDDS) approach (Owen et al., 2009) is applied to discuss whether the findings on process, people and technology are relevant towards the construction industry. The IDDS approach is used to elucidate that these findings are factors that should support performance improvement in the construction industry. The construction industry is under pressure to reduce project delivery times and costs despite increased complexities in today's projects (Jaafari, 1997, Bogus et al., 2005). The approach challenges traditional industry structures and contractual processes, which corresponds with the research presented in this paper.

## **2. Research method**

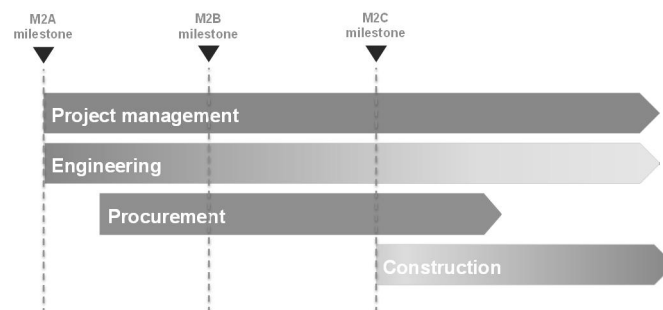
The research is qualitative and based on case studies. Data is gathered from three case projects in the oil and gas industry through Kvaerner, a Norwegian EPC (engineering, procurement, construction) contractor, executed as EPC contracts. The primary case project has been the topside for one of four platforms of the Johan Sverdrup field on the Norwegian continental shelf, which started detailed engineering in 2015. Secondary case projects have been the topsides for the Edvard Grieg platform and the Eldfisk platform, delivered in 2014. All three consists of a combined living quarter and utility module. Data collection has been conducted by the author through interviews, supplemented with relevant company and project documentation. Data has primarily been gathered from 8 semi-structured interviews, with the use of interview guides, from March 2013 to October 2015. Four of the interviews, had main focus on transition between engineering and construction, three on the use of PEM, and the last on the use of BIM. The average length of the interviews has been 1 hour 47 minutes. Each interview has been conducted with one to two interviewees in key positions in the cases, including Project Manager, Information Manager (responsible for all aspects of information handling in the project), and Head of PEM. The stepwise-deductive-inductive (SDI) method (Tjora, 2012) has been applied to analyze the collected data. The principle of this method is to work stepwise from data to concepts or theories (inductive) and verify these theoretically to the more empirically (deductive). The collected data has been transcribed and used to develop “empiric-close” coding that reflects the contents of the text. The codes have been sorted into larger groups of themes, called categories, and used as a basis to develop concepts that capture central characteristics of observations and findings. This is similar to what Halkier (2011) has described as “category zooming”, as a way to generalize qualitative data. This is a three-step process, from coding and categorizing, through tracing of systematic relationships between categories and finally aiming for conceptualizing.

### 3. Process

#### 3.1 Parallelism and build sequence

According to Lee et al. (2005), parallelism, or concurrent engineering and construction, is gaining popularity due to the increased demand for shorter time frame of projects. In Kvaerner, parallelism gives greater challenges than if construction can be deferred until after the engineering has completed. The extent of the challenge depends on client's requirements to the contractor. The client sets the scene in terms of how complex the process becomes, by setting the time frame from the contract is signed to delivery date. Longer time frame gives more predictability between the phases. Shorter time frame gives a higher degree of parallelism between the phases. The more parallelism there is in a project, the greater demands are put on the participants in that they know what the sequence and the quality requirements of the project is. This is similar to what Succar (2009) has defined as "BIM stage 2", where engineering and construction is in parallel, and is driven by construction providing design-related services, and engineering increasingly adding construction and procurement information into their BIM. Integration of engineering and construction is not new, and similar terms and techniques have been used to respond to the time and cost pressures in projects (Jaafari, 1997). Parallelism is similar to concurrent engineering (CE), where the aim is to reduce the total delivery time and cost of a project by overlapping activities that are normally performed in a sequence (Bogus et al., 2011). In the last decade, the concept of integrated concurrent engineering (ICE) have also been introduced, where the focus is to "speed up the process by increasing task parallelism and reducing response latency and lag, which decelerate legacy multi-disciplinary construction engineering processes" (Alhava et al., 2015).

Engineering influences all project phases. In Kvaerner's PEM, the design phase consists of three stages with corresponding milestones (M2A, M2B and M2C). During these stages, the BIM is developed to a quality level where the design and all interfaces (between disciplines) are frozen. When the last milestone, M2C ("Global design complete"), is reached, the the BIM should have reached a defined quality level so that the engineering subcontractor can start issuing drawings, and Kvaerner can start construction (see principle in Figure 1).



*Figure 1 Parallelism between E, P and C (Kvaerner, 2013)*

With parallelism in EPC contracts, it is important to be aligned in the sense that there is a correlation between how one conducts engineering and how one plans to build. A common challenge is that Kvaerner will build in a sequence, which is cost effective for them, while the



engineering subcontractor would prefer to think in a totality until design is complete. In order to get drawings and materials at the right time when construction is pushed in parallel with engineering, Kvaerner has made a build sequence that engineering and procurement must know of, because they will need to deliver according to it. The ambition to Kvaerner is that engineering is conducted in an order that fits into the build sequence that gives the fewest possible hours in the workshop. The dilemma is that the engineering subcontractor do not know Kvaerner's build sequence, and Kvaerner does not know how the engineering subcontractor conducts their engineering deliveries. Kvaerner's PEM can describe how it is done and at what status deliveries should be on each milestone, but Kvaerner has to tell the engineering subcontractor what they need to deliver. Kvaerner has therefore spent a lot of time with the engineering subcontractor to explain how Kvaerner's build sequence is and what they require of engineering deliveries, including drawings, materials as well as equipment components, to support this, so that the engineering subcontractor can adapt its engineering deliveries to Kvaerner's build sequence.

### **3.2 "Right the first time"**

According to Kvaerner, the various input factors must have come to a certain level in quality and progress, on a given milestone. If someone goes too far and others too short, it will not be "right the first time". In the design phase, all disciplines should know at any given point in time how far they should have come with their design. If a discipline has come too short and not fulfilled the requirements at a milestone, they can influence the others when they are finished. If a discipline has gone too far, the discipline might need to redo much of what is done while the other catches up, because the discipline have made assumptions that are not met. Similarly, Lee et al. (2005) has stated that successor activities that have to start without complete information from predecessor activities, may lead to a chain of wrong decisions in other related activities. Whoever succeeds to optimize the process best will be the cheapest and fastest.

"Right the first time" is doing it right the first time and not having to do it over again, and is something Kvaerner strive for. Kvaerner's PEM supports "right the first time" by defining milestone requirements and associated discipline checklists to all stages in each project phase. In each project, the client will have contractual milestones. The milestones defined by Kvaerner in their PEM are distributed as parallel as possible with the contractual milestones to the client, so that it is consistency between these. It is also to avoid communicating a different message to the project team in every project. When the final milestone in the design phase, M2C, is reached, the objects in the BIM are at a quality level that one can begin issuing drawings for construction. The design is frozen, and should by definition not be changed. At the M2C milestone, engineering should have fulfilled the milestone requirements to satisfy Kvaerner's build sequence, so that Kvaerner safely can start construction. This is similar to what Schade et al. (2011) identifies as a quality gate, where design maturity is synchronized and evaluated, and reflects the detailing of the design, in a concurrent engineering approach. When Kvaerner conducts projects with engineering and procurement on a subcontract, both parties has their own PEM. Like Kvaerner, the engineering subcontractor has organized their work in a way where they have milestone requirements and associated checklists (for each discipline). To make sure the engineering subcontractor has come as far as required on the last milestone to start deliveries to construction,

their milestone is checked against Kvaerner's milestone (M2C). The methodology is based on the fact that the requirements that Kvaerner has made for the last milestone in the design phase (M2C), in terms of what the disciplines should deliver and to what quality level, is adapted to Kvaerner's build sequence. The requirements for each discipline at the M2C milestone and the corresponding milestone to the engineering subcontractor is compared through a GAP analysis, to see if the engineering subcontractor are close to fulfilling the requirements at the M2C milestone. They identify the gaps between the two milestones, and go through the checklists for all relevant disciplines, and look at where they need to increase the requirements. Kvaerner wants the engineering subcontractor to use their own PEM, but with certain milestone additions and adjustments, to satisfy Kvaerner's build sequence. The main reason for this is that the barriers for adapting new milestone requirements are lower when using a familiar PEM. If the engineering subcontractor meet the requirements in the last milestone in the design phase, it is very likely that Kvaerner's build sequence can be used.

## 4. People

How do you merge engineering and procurement with construction? According to Kvaerner, when working as an EPC contractor with control over both engineering, procurement and construction, rational considerations can be made in terms of how spending and earnings should be, in order to optimize the bottom line. It is the company that determines the optimal sequence and the desired order of deliveries from engineering, procurement and construction in each project. When there are two separate companies, the interests of one may not always easy favored by the other because of different economic drivers. With engineering and procurement on a subcontract, there can be different contract models between the EPC contractor and the engineering subcontractor. As soon as these two parties have a contract regime that exist between them, the engineering subcontractor will work according to their drivers - that often do not correspond with the drivers the EPC contractor has. It is typically the contractual terms to the engineering subcontractor that drives them. If they have day penalties on deliveries, or reduced compensation if they spend too many hours, they work according to that. But then it might be that they are not as concerned about whether the quality of the deliveries is 100%. According to Jaafari (1997) each actor in a project tends to manage their own scope in a way that minimizes their own exposure to risks and maximizes their gain, which may lead to divergence of objectives of the parties from project objectives.

According to Kvaerner, the engineering subcontractor can work according to a fixed price or paid per hour with a profit, in a subcontract. They must take responsibility for their deliveries - either through performance milestones or through milestones with day penalties. If drawing quality is too poor, drawings must be recalled and updated on their own expense. A subcontract can work out if the contractor requires defined drawing deliveries, and can set fines or bonuses on deadlines. They can probably agree on a better order of the drawings (in relation to the build sequence). Kvaerner emphasizes that it is important that the contractor and the engineering subcontractor have common drivers related to engineering deliverables. This leads to another variant, a joint venture, where the two parties share a common bottom line. According to Owen et al. (2010), contractors can operate integrated on individual projects, or establish temporary joint ventures, to

provide cost, time and delivered quality benefits through more integrated processes. The understanding throughout joint venture is that if the engineering subcontractor (or contractor) do not manage to deliver, there will be no bottom line to share. For Kvaerner this is the most effective, because then they do not need to be as aggressive in trying to follow up the engineering subcontractor as in a traditional subcontract. Then they are partners, both knows what applies, and have the same drivers. In the agreement Kvaerner has made with the engineering subcontractor in the primary case project, the parties have established a joint venture for a joint EPC, where they are "joint and several" responsible. This means in practice that if one part is not performing, it has a consequence for the other. If one part goes bankrupt, then the other part must complete the work the other should have done. They are mutually dependent of both parties performing and they share profits on the bottom line in a percentage distribution. It is a model that better prepare for an improved transition between engineering and construction, because they have a common driver. The engineering subcontractor only get their expenses covered through invoicing, and only get the profits from what is left of the cash balance in the end. This means that the engineers at the engineering subcontractor should be motivated to perform and deliver as planned. If not, they can go from sharing profits to covering deficits afterwards.

It might be that despite establishing a joint venture, the motives for the two partners can be different. It may be so that the engineering subcontractor that works for Kvaerner can lose more on another contract than the contract in question, if they do not make a greater effort. They might choose to withdraw personnel and move over to the project that has greater challenges or that has a greater risk associated with it. The engineering subcontractor that works for Kvaerner can also work for several other construction yards, which has no build sequence, not the same requirements to a build sequence, or does not have the same requirements to a PEM that Kvaerner has, which can make the adoption more challenging to accomplish. In this case they must reach down to every discipline and get them to understand that now they need to satisfy another build sequence, which is another way to deliver on. Kvaerner point out that there are mechanisms that can support this. They can both select key personnel. Both parties must then approve the competence of key personnel that the other deploy into the project. By exchanging CVs on key personnel, they both can be assured that they are putting on experienced and competent personnel, on equal terms. There will be penalties if any of the personnel are withdrawn from the project. This will prevent the ability to juggle too much with personnel and competence. Both parties should feel equally safe for doing the best they can. A key to influence and train engineers is the use of a PEM with common milestone requirements, so that engineering can be executed in a manner that is adapted to Kvaerner's build sequence. Because the bottom line is the main driver, the project team do not need any additional drivers. As long as Kvaerner manage to explain what the requirements are and why the requirements are the way they are, the engineering subcontractor get insight in what is needed to be able to increase the bottom line. To support this, they carry out what they call inductions, which is an introductory package for the engineers as they come aboard the project.

For Kvaerner, success is also related to the competence and experience of the project team. Most project participants bring along experience from the last project – in terms of both methodology, requirements and deliverables. It will always be a challenge to include those who were part of the project last time when an engineering subcontractor mobilizes for a new project together with

Kvaerner. If they repeatedly get more common projects ahead, they can adapt to each other better. Kvaerner has experienced that if they have 70% engineers who have been part of a project team that worked according to the requirements in Kvaerner's PEM, there is a great chance that it goes better in the new project than the last time. If they have 30% engineers who have worked according to the requirements in Kvaerner's PEM and 70% beginners, there is a great chance that the new project will not turn out well. To succeed in future EPC projects, it is important to seek a form of strategic alliance with the preferred engineering subcontractor, and use the same from project to project. Experiences from strategic alliances that Kvaerner has today with engineering subcontractors, indicate that there are virtually no conflicts.

## 5. Technology

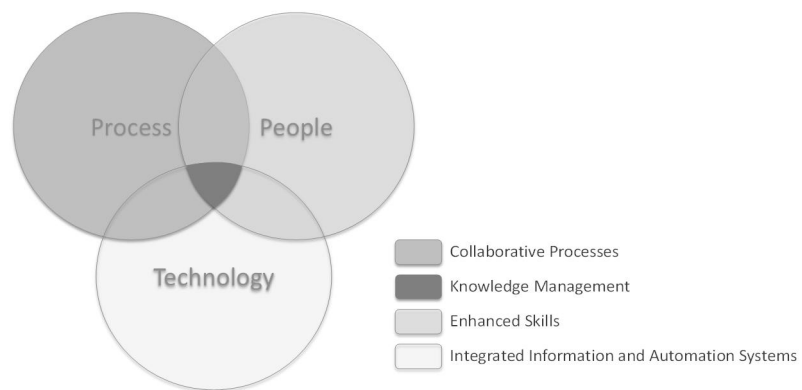
When the engineering subcontractor works in the BIM without the contractor having set the boundaries for the different sections, they work relatively unhindered. Disciplines work with the entire platform, because many of the objects modelled go through several sections. Kvaerner has experienced that to get a discipline to split the model in objects that are going onto to the different sections, when the boundaries are set, is a challenge to accomplish, and increases the complexity, with many interfaces. It is an added cost, and more time consuming, because the discipline must spend time to go in and out of the sections. There is a maximum limit to how much parallelism one can manage in that context. The splitting of the BIM towards fabrication and construction are based on the main areas as defined by the contract. The sub areas, called fabrication assemblies, are defined by Kvaerner to control the parts that are sent out for fabrication. All necessary documentation, including drawings, are related to each fabrication assembly. FAS (fabrication assembly section) express the horizontal area, and FAV (fabrication assembly volume) the volume above. FAS is the first that comes into production. FAV is established when they have added several sections that are finished. Some of the planned activities go towards the area, while some of the activities goes towards the volume. There are certain activities that requires several volumes composed simultaneously. For instance, a cable can not be cut from volume to volume, and must be drawn as one cable. Cable activities are planned against all volumes it goes through. A pipe can be split, because it must be welded together.. Piping activities may be connected against each FAV, because they can draw out the pipes and welds between them. Fabrication assemblies are similar to what Jaafari (1997) define as clusters, referring to particular parts of the project. Clusters can include relevant front-end activities, procurement and construction activities. Each cluster can be assigned to a team and executed as an integrated part. Similarly, Luth et al. (2013) states that sequencing knowledge and methods, in addition to construction means, can be incorporated in the BIM, in order to reach a sufficient quality level to produce drawings for construction.

Anumba and Evbuomwan (1997) define the aim of concurrent engineering (CE) to reduce lead times and improve quality and cost by integrating fabrication in design, and maximizing parallelism. When engineering starts it is required that all large and heavy equipment are identified. According to Kvaerner, the disciplines need all design parameters of what they call critical packages (weight, where bolt holes are, where pipes are to be connected, how cables should be plugged in etc.). That is governing because the disciplines need to get this to fit together

(the floor needs to support the weight, any rotating equipment must withstand the rotational forces etc.). The bigger and more expensive equipment, the longer time it takes to fabricate. It is therefore important to get this equipment ordered as early as possible, to get the vendor drawings and to get it delivered on time. The sequence of purchase orders is made based on criticality. Kvaerner define criticality in terms of how much equipment (i.e. the information on the equipment) are of importance for the design development, and is categorized from 1 to 3, where 1 is the most demanding equipment ("long lead items") and 3 is the least demanding. Preliminary information of equipment is based on the initial purchase orders and used as important input to the fabrication assemblies. The information is updated when the orders are finalized.

## 6. Discussion

Are the findings on process, people and technology in this paper relevant towards the construction industry? The IDDS approach, which aims to utilize BIM and make sure that improvements in construction projects are based on a combination of process, people and technology, is used to assess this. IDDS consist of four main elements; collaborative processes, knowledge management, enhanced skills and integrated information and automation systems (Owen et al., 2009). Process, people and technology are closely related and mutually dependent. Findings on process can be related to collaborative processes and knowledge management, where the latter also have a close interface towards people and technology. Findings on people can be related to enhanced skills, while findings on technology can be related to integrated information and automation systems (see illustration in Figure 2). The conditions and main challenges each of these elements address, have been briefly identified, followed by how key findings on process, people and technology can address these.



*Figure 2 Relation between process, people and technology and the four elements of IDDS*

**Collaborative Processes:** Improved design and delivery through better coordination and integration is essential. To support this, information technology tools will need to provide increased capability for knowledge sharing and development, rather than for just information exchange, aggregation and storage. Collaborative approaches, linked with an effective knowledge management system, would facilitate this. Further benefits may result from adoption of new approaches to work processes being developed in other sectors (Owen et al., 2010). Kvaerner's ambition is always to build in as short time as possible and have as high parallelism as possible

and as few working hours as possible, but at the same time meeting the quality requirements. To be able to work integrated, the EPC contractor must describe the build sequence for the engineering subcontractor, so that they manage to deliver their drawings and materials into that specific sequence. PEM shall ensure that the status on the engineering deliveries at the last milestone in the design phase satisfies Kvaerner's build sequence.

**Knowledge Management:** Codified knowledge in companies typically exists within individual groups (discipline, trade, function) and is seldom shared with others. Applying knowledge management, which includes codifying, using and constantly updating critical knowledge and business processes, is only done in a few leading companies (Owen et al., 2010). PEM supports "right the first time" through milestone requirements, to make sure engineering has come as far as required to start construction. Kvaerner's milestone requirements in the design phase are compared to the engineering subcontractor's corresponding milestones. The gaps are identified, and additional requirements are added to their milestones. In that way the engineering subcontractor can keep their own milestones but with certain additions (or deductions) to support Kvaerner's build sequence. The core to success is that Kvaerner is able to get the message out to the disciplines. Kvaerner's PEM, which is knowledge management in practice, has two functions in respect to that; tell the disciplines what they should have done at a given milestone and to check whether it is achieved.

**Enhanced Skills:** Increased performance requirements and complexity in construction increase the need for integration skills. Furthermore, project management in integrated projects need to focus on personnel with shared technical knowledge and integration experience as key selection criteria. Knowledge of prior projects and current requirements, will foster integrated work processes both between and within specific project phases and major activities (Owen et al., 2010). A joint venture with a common bottom line, that Kvaerner and the engineering subcontractor has established, with clearly defined project goals, which the parties have to align to, will increase the motivation to integrate for both contracting parties. The main advantage of an incentive-based contract, such as joint venture, is its potential to unite the objectives of the project team with project objectives. Kvaerner must get the engineering subcontractor to adapt to their build sequence and not what they have done towards other EPC contractors. That is what Kvaerner and the engineering subcontractor have spent time on in the relevant case project. If Kvaerner manage to get a new project with a majority of the same personnel, it would further improve integration.

**Integrated Information and Automation Systems:** Moving towards partial integration and automation of engineering, procurement and construction, will increase the overall performance of a project. This includes extracting information for fabrication from the design model. Further progress will require providing more complete design information models for use in in construction (Owen et al., 2010). This is what Kvaerner has moved towards, when they split the BIM in sub areas, called fabrication assemblies. These are developed to be able to define and control what is sent out for fabrication. Drawings and all other relevant information is related to each fabrication assembly. Kvaerner has three categories of criticality, which is related to design and delivery time on equipment. Information on equipment is based on the purchase orders, and

will be updated as the orders are finalized. This is used as important input to the fabrication assemblies.

## **7. Conclusions**

This paper has identified how transition from engineering to construction can be improved, based on experiences from offshore projects in the oil and gas industry through Kvaerner, executed as EPC contracts (design-build), with engineering and procurement on a subcontract. The results are structured according to three interrelated dimensions; process, people and technology. The first dimension, process, is related to parallelism and build sequence. Construction is pushed in parallel with engineering, because of the short time frame from contract is signed to delivery date. To get deliveries at the right time, Kvaerner has made a build sequence, according to their project execution model (PEM), that engineering and procurement must know and deliver according to. At the last milestone in the design phase, M2C, the design should be at a quality level that is required to start construction. PEM supports “right the first time” by defining requirements on the milestones in the design phase. The M2C milestone is checked against the corresponding milestone to the engineering subcontractor. The gap is identified and any additional requirements are added to the milestone to the engineering subcontractor, so that they can satisfy Kvaerner’s build sequence and deliver “right the first time”. The focus for the next dimension, people, is related to common incentives and drivers, and how Kvaerner can make sure that the engineering subcontractor adapt to the build sequence and align their milestones. Through a joint venture, where they share profits on the bottom line in a percentage distribution, the incentives are higher for both parties to satisfy, compared to a standard subcontract, because they are mutually dependent on each other. It is crucial that Kvaerner can influence the disciplines to adapt the design and deliveries to Kvaerner's build sequence. Success is related to the use of experienced and competent personnel on both sides in the project team that are commercially conscious to what mechanisms apply in the contract, and act according to that. The last dimension, technology, is related to the use of BIM and how it must be split into sub-areas, fabrication assemblies that contain all relevant information and is optimized for Kvaerner’s build sequence. Criticality related to lead-time on equipment and availability of correct vendor information at the right time will be important input to fabrication assemblies. The IDDS approach (Owen et al., 2010) is applied to increase the relevance of the findings towards the construction industry. It consists of four main elements and identify challenges in the industry on BIM and process, people and technology. Several of these challenges have been addressed with the findings in this paper, which increases the relevance towards the construction industry. Future research will focus on gathering additional data related to process, people and technology and analyze that to further develop concepts, for adaption towards the construction industry.

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# Transformation of Emerging Building Materials Reuse Industry through Mapping Sustainable Architectural Design Processes using BPMN

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## Abstract

In the United States, new building material reuse and de-construction businesses are currently emerging as an alternative to demolition contractors. A national association organizes a bi-annual conference and vendors from all around the country gather to share their business experience, challenges and networking opportunities. These businesses are helping society by reducing material waste, achieving LEED Resource Reuse credits, and creating job opportunities. They suffer, however, from the absence of a "system of information exchange" that would streamline their business processes, establish a supply-and-demand chain, and connect vendors, brokers and contractors with designers and architects.

This study presents an innovative restructuring of the traditional Design-Bid-Build process that enables the reuse of resources. The restructuring transforms the DBB project delivery method into an Integrated Project Delivery method by including the sustainability stakeholders in the early phases of the design process. We developed this model by capturing expert knowledge using a Delphi research protocol and the Business Process Modelling and Notation standards (BPMN). The proposed business process mapping workflows are integrated with the BIM Project Execution Planning Guide developed by the Computer Integrated Construction Research Program at the Pennsylvania State University (2010). Our work also identifies the critical decision nodes within the proposed process maps and suggests a decision-support framework that aid architects and building stakeholders when integrating sustainable building solutions regarding reusable materials. The Knowledge Capturing Process utilized in this research was applied using a qualitative method and a modified Delphi research protocol with the research participants. Triangulation with literature and built case studies were performed and the results were integrated in an illustrated detailed blueprint set of BPMN maps, which were then used to reach consensus with the industry stakeholders.

**Keywords:** Building Materials Reuse, Waste, Process Mapping, Decision Making, Resource Based Design Build, United States Materials Marketplace

# 1. Introduction

Waste from building construction and demolition activities are increasing everyday. Landfills almost everywhere in the world - except the United States - have reached their capacity and despite the environmental and economical global crisis, we continue to generate more waste than ever. When we realize the negative impacts of deconstruction and demolition activities on the environment, it becomes necessary to think about innovative ways of reusing and recycling building materials in new construction (CIB, 2002, Dorsthorst and Kowalczyk, 2002) or, perhaps better, recycling our thoughts about making use of materials waste. Studies show that construction and demolition activities are the primary source of waste worldwide. For example, demolition waste in England alone has been estimated at 91 million tons in 2003 (Osmani, 2008) and construction and demolition waste constitute about 40% of the total solid waste stream in the United States (USGBC, 2003). As critical and creative players in the building making industry, architects are confronted today with their role in waste crisis. We can find this sentiment expressed in Kevin Lynch's last book, *Wasting Away*, when he suggested that: "*Architects must begin to think about holes in the ground and about flows of materials*" (Lynch and Southworth, 1990). Although known primarily for his transformational inventions in energy, Thomas Edison (1847-1931) also warned us that, "*Waste is worse than loss. The time is coming when every person who lays claim to ability will keep the question of waste before him constantly. The scope of thrift is limitless.*"

Traditionally, architects' primary focus is on building design and construction; very little thinking is spent on un-building and deconstruction (Falk and Guy, 2007). Architects typically view the building as permanent structure that should make lasting and timeless statements, and very few think of what happens to the built environment at the ends of its life. An increasing body of knowledge on waste management and waste diversion from construction sites already exists, but almost none is focused on the role of the architect in reducing waste. The questions that arise for this problem include: What is the role of the architect in improving waste prevention and reduction through design (Erkelens, 2003) How can salvaged and reclaimed building materials be incorporated in new construction? And what is the process of evaluating and selecting salvaged materials?

The emerging building material reuse vendors and de-construction contractors in the United States are faced with big challenges from the absence of a "system" to streamline their business process, establish a supply and demand chain, and connect them with designers and architects. Nevertheless, additional obstacles, such as quantities required, storage, scheduling and recertification, add more pressure on this industry to get it off the ground. Successful case studies of reuse in building projects still remain as rare, experimental and unique. , They also differ greatly from one to the other in the incorporation of building material reuse. One example is the Big Dig House in Lexington, MA, designed by Boston-based architecture firm, Single Speed Design, which successfully reused steel beams and concrete slabs salvaged from the Big Dig project in Boston (Fettig et al., 2006). The processes of designing and implementing reused materials were unique and very specific due to numerous factors. Understanding the process of how these initiatives became successful is an important part of this study.

## 2. Building Materials Reuse Market

### 2.1 Current Status

Although there are substantial environmental, economic and sustainability benefits for using reclaimed materials, the market is virtually untapped and extremely fragmented. At the time of this writing, only 1% of reclaimed materials are used in new building projects in the UK (Gray, 2011), a percentage that should be higher. One of the barriers has been a lack of information about sourcing and the reuse of materials in design and construction, including knowledge of specifications, standards, liability and performance. But there are economic barriers too, including the cost of extraction in deconstruction, the limited flexibility and quantity of reclaimed materials, and problems of storage and the double handling of materials between sites. In addition, medium to large building projects cannot take advantage of the reclamation industry, because the salvage supply chain is not yet established nor equipped to deal with large orders.

The United States Environmental Protection Agency (EPA) has listed a number of organizations under the Construction & Demolition Materials subcategory of its Waste and Resource Conservation category. The EPA stated that throughout North America, hundreds of used building material stores sell materials for construction and renovation projects. Materials (such as used lumber and bricks) and other items (such as doors and windows) are salvaged primarily from remodelling projects, pre-demolition salvage, and the growing practice of deconstruction that leads to the selective disassembly of buildings for the reuse and recycling of parts. Among the list is the Building Material Reuse Association (BMRA), which is a nonprofit educational organization whose mission is to facilitate building deconstruction and the reuse or recycling of recovered building materials in the United States. Members of BMRA include deconstruction contractors, salvage businesses, architects, recycling coordinators, etc. The organization operates on a national level in North America; in 2011 it reported that the number of reused building materials centers has grown rapidly over the last 15 years, estimated at over 1000 nationwide. The organization offers information on building materials reuse, deconstruction, and green building practice. It organizes a national conference on building materials reuse, deconstruction, construction and demolition waste recycling, and offers training and other educational opportunities. Although this association has been organizing conferences nationwide biannually for more than 15 years, its members are still suffering from a system that can connect them to architects and designers and streamline the sourcing and procurement workflow. The “yellow pages phone book” style of listing deconstruction businesses and salvaged materials vendors on the association website has failed to help this emerging industry get off the ground, with the result that there are still limitations on the supply and demand chain.

A serious attempt to establish that missing supply demand chain is currently being realized. Based on the idea of the Circular Economy, the project titled ‘*United States Materials Marketplace*’ was launched with the support of three major world organizations: the United States Business Council for Sustainable Development (USBCSD), the World Building Council for Sustainable Development (WBCSD), and the Corporate Eco Forum (CEF). The United States Materials Marketplace was initiated as a pilot project in the summer of 2015 to test the feasibility of a

national exchange where traditional and non-traditional industrial waste streams could be matched with new product and revenue opportunities. The US Marketplace is currently establishing the software platform of materials exchange on the web, a framework that we suggested in our article (Ali, 2012), proposing that a national level materials exchange repository was critical to the success of connecting with architects. The US Marketplace is currently focused on wasteflows from large industrial companies such as General Motors, Nike, and some building materials manufacturers such as Armstrong. Manufacturers from the building product sector will join the marketplace as it gains momentum.

### **3. Resource Based Design Build**

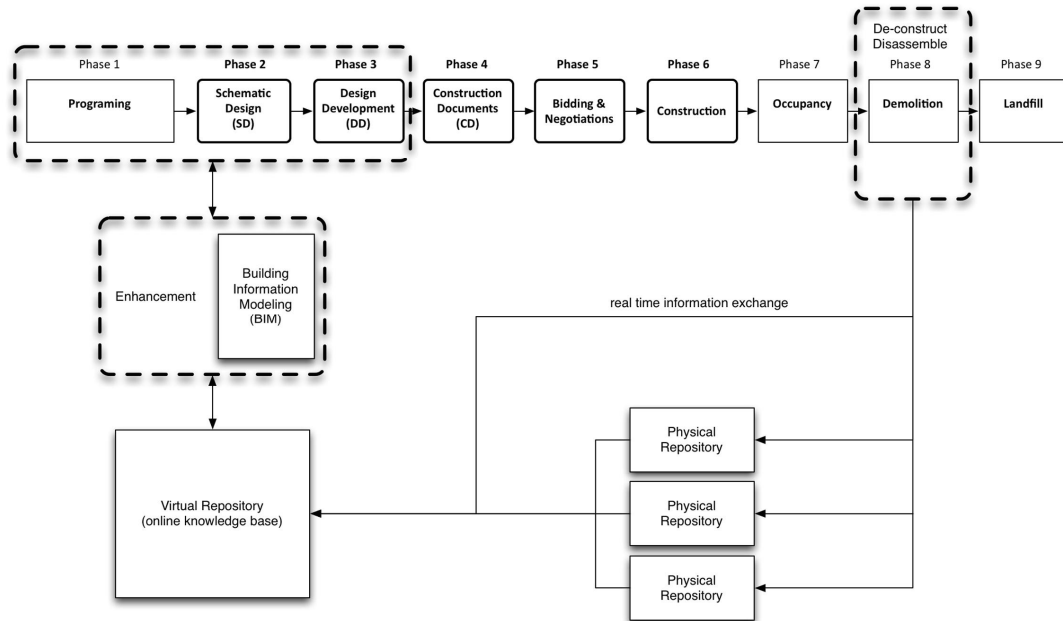
The astonishing volume of solid materials waste represents not only a demand on landfill sites but also a disregard for the material and energy resources contained in these components (Thormark, 2001). While there is a significant body of research related to construction and deconstruction of buildings and construction waste management (Osmani, 2005) the majority of these studies or proposals only indirectly suggest the importance of the architect in this process. Indeed, it could be argued that, for non-residential buildings, the architect is the key decision-maker in designing for reuse. While many architects would consider the reuse of salvaged building components in their designs, and a few architects have already implemented designs with a significant amount of component reuse, a current barrier to wide-scale implementation of design for reuse strategies is the lack of an easily accessible and usable platform for comparing and evaluating alternative reused building components. We propose that this platform could easily be connected to Building Information Modeling (BIM) through a decision support framework. Through this study, a new decision-support structure for designing buildings with reused materials will be developed. The outcome will be a new mechanism that will transform the architectural design process to one that better supports design for reuse. The broader impact will be a reduction in the volume of building-related waste, the creation of new job opportunities with emerging de-construction industries, and a profound impact on the US economy. The Dutch firm SUPERUSE Studios suggested the term “Resource Based Design” as they explored design with wasteflows through their Harvesting Map platform in the Netherlands.

#### **3.1 Proposed Design Scenario**

Our proposed design scenario is envisioned as follows: an architect designs a new building while utilizing Building Information Modeling (BIM). The proposed building is “dissected” as a process in BIM and an inventory of the building components is generated. This component inventory is archived for future reference and is used as input to the decision-support process. Concurrently, other buildings nearby or within (harvesting map) proximity either have been or are in the process of being de-constructed. An inventory of the available components from these de-constructed buildings is generated, including essential information of the necessary decision-making attributes, along with similar information from manufacturer refused products (wasteflows) and salvaged warehouse stores and vendors. A platform for all of the above information is called a “Virtual Repository,” which will be an online local/national/global library of reclaimed and salvaged building materials and components. This Virtual Repository will be linked to all

available Physical Repositories (reclaimed materials warehouses, deconstruction sites and industrial manufacturers) and live updated with all available materials with necessary information the design team needs in the design process. A simple representation of the workflow can be seen in Figure 1. (Note that the architectural design process is not linear but investigative in its nature).

*Figure 1: The Proposed Design Scenario (Ali, 2012)*



In the future, the previously mentioned BIM inventory from today's design will be activated when the building is de-constructed to provide an efficient mechanism for inventorying salvaged components. For the proposed new design, each component in the new building is compared with components in the Virtual Repository. Here comparisons are processed through the decision-support framework using the decision-making attributes. These attributes include, but are not limited to, assessment of age, possible fatigue and weathering of the reused component, structural integrity, history, appearance, size and dimensions, and ease of alteration. The matching process will be both direct and indirect based on the processing of the attributes. Direct matches are when a needed component, such as a steel beam, is matched to an available component. Indirect matching will occur when the evaluation of attributes identifies a salvaged component that can be potentially adapted for use as a new component (Roberts, 2005). This process can be referred to as creative re-purposing (for example, when a set of exterior wall panels can be reused as suspended ceiling panels). In addition, the decision support process compares other factors such as costs, embodied energy, and transportation distance. As part of the attributes for reused components, information such as images, as-built drawings, specs and other visual information of the component, are also accessible to the design team.

### 3.2 Critical Assumptions

There are three critical assumptions that need to be addressed when building the decision support framework and mapping the design workflow for using reclaimed and salvaged building materials and components. While these assumptions will be critical to the ultimate success of this research, the focus will be at the building design level with the assumption and recognition that these other levels will influence the ultimate platform of the proposed framework. These assumptions can be summarized as the following:

1. Establishment of a Supply-Demand Chain mechanism between de-construction sites and reuse stores and salvage warehouses. As the market of salvaged and used materials becomes viable, widely acceptable and profitable, a refurbishing process such as modifying, sorting, coding and re-certifying will take place. Collectors, re-manufacturers, wholesalers and retailers will convert the salvaged materials into usable products. These wholesalers and retailers will perform a vital function of aggregating the supply and demand system. The design team will recommend from this supply chain's inventories and purchasing mechanism will be established.
2. Establishment of a Standardized Universal Online Virtual Marketplace for Reclaimed Building Materials. In this study, the online marketplace of reclaimed and salvaged building materials and components is called "The Virtual Repository." It is described in the previously proposed design scenario (figure 1) as an essential component of the decision framework. The development of this marketplace will depend heavily on the successful identification of a number of attributes and necessary information related to the reclaimed and salvaged building materials and components. It is our vision that this online marketplace will be connected with salvage warehouses and online exchange vendors through a system of information exchange. This could be similar to, for example, the on-line inventory database from the used car parts industry.
3. Time and Scheduling of Purchasing Materials. The decision on whether or not to use reclaimed and salvaged building materials depends very heavily on issues related to the purchasing these materials. In a typical design process, the timing of comes after the bidding phase. The decision of purchasing reclaimed and salvaged materials, on the other hand, needs to come very early in the design phase in order to secure these items.

## 4. Experts' Views on Business Process Mapping

The data, which we collected from a modified Delphi mining process and face-to-face interviews, were largely inductive (meaning that these specific data leads to general patterns). Therefore, a whole text analysis that involved identifying, coding, and categorizing patterns in the data was conducted. Since literature suggests that there is no single correct way to analyze qualitative data, our analysis wasn't a linear process. Instead, it involved spiraling back and forth between various stages. Strauss and Corbin argued that the grounded theory procedure could be stopped after step six if the researcher is only interested in a thematic analysis or concept development (Strauss and

Corbin, 1998). Following the solicitation request from our preliminary forecast questionnaire, two groups of participants were identified for further data collection. The first group was face-to-face interviewed (Table 1), while the second group was virtually interviewed. The actual participants in the face-to-face interviews were nine and nevertheless satisfying to the researcher. The structure of the interview sessions was designed to elicit expert judgment and opinions to structure the findings efficiently. Knowledge capturing process was carefully planned in order to maximize the quality of data gathered.

*Table 1: Face to face interview participants*

<i>Interviews</i>	<i>Building Material Reuse Stakeholder</i>
<i>Interviewee 1</i>	<i>Community development (Habitat for Humanity)</i>
<i>Interviewee 2</i>	<i>Government agent</i>
<i>Interviewee 3</i>	<i>Architect</i>
<i>Interviewee 4</i>	<i>Building Materials Reuse Consultant</i>
<i>Interviewee 5</i>	<i>Deconstruction Contractor and reuse store</i>
<i>Interviewee 6</i>	<i>Reuse store and BMRA member</i>
<i>Interviewee 7</i>	<i>Research Architect and Government Agent (U.S. Army Construction Engineering Research Laboratory)</i>
<i>Interviewee 8</i>	<i>Researcher, Industry Educational Association - BMRA</i>
<i>Interviewee 9</i>	<i>Deconstruction Contractor</i>

## 4.1 Knowledge Capturing Process

Each participant of the focus work group remained anonymous. That is, the members were individually asked the same set of questions in every round of the Delphi process, without disclosing their identities to the others. Consequently, participants did not have to worry about being forced to a final outcome in the first round of the opinion soliciting sessions. They had the opportunity in succeeding rounds to modify their answers in light of the responses from others or stick to their original opinion. Rounds of these opinion-gathering sessions were conducted until the group reached a consensus. The same set of questions was sent to other stakeholders who expressed interest in participating in the study but who could not attend the group session. After the first round of interviews, the researcher organized, coded and analyzed the responses, then prepared a second round of questions which were conducted through an online survey tool. We used our initial UML maps - as seen in figure 2 - which presented the traditional DBB workflow to guide the participants and engage them in the discussions

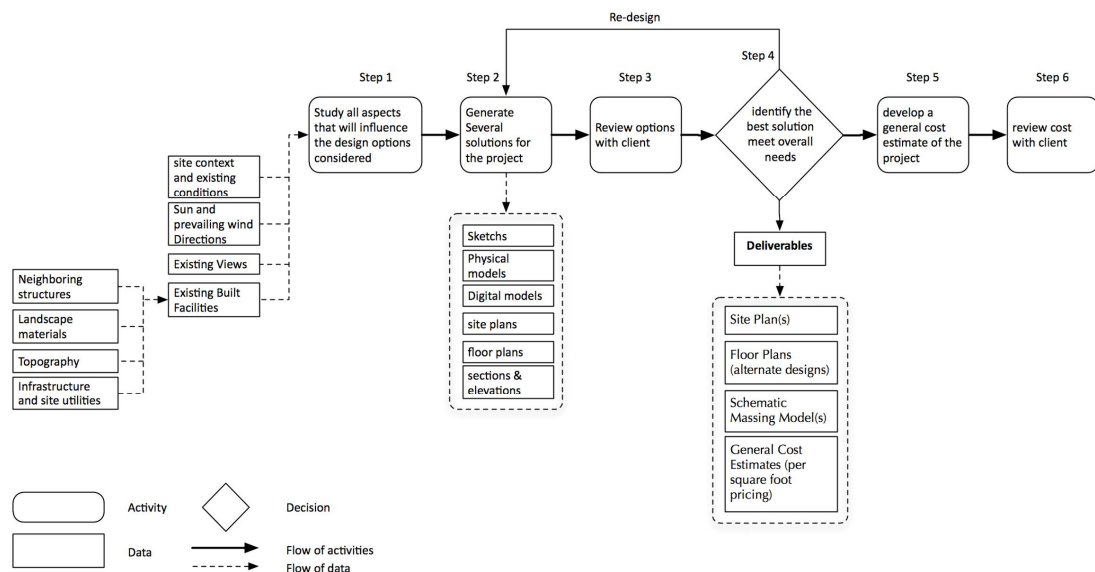


Figure 2: Traditional DBB Schematic Design Phase UML Map Workflow (Ali, 2012)

## 4.2 Designing the Review Process and Workflow Mapping

Essential to mapping the building materials reuse design process were the design and construction of a number of flowcharts and maps. A standard modeling language from the Business Information Technology domain was consistently adopted throughout the mapping process; a series of initial UML activity diagrams (later updated to BPMN diagrams) illustrated critical participants, communications, data and contingencies. Specifications of the knowledge artifacts involved in the process were structured in a concept map. The UML activity diagrams represented the Building Materials Reuse process (BMR) incorporated in new construction. Three major players in the process were identified: the architect, the BMR consultant, and the Reuse store vendor/broker. All processes were supported by data and information, which were placed in a separate swim-lane along with the other swim-lanes for the participants (Figures 3,4). The flow of information is represented using dotted arrows. Solid arrows represent the start and the end of each activity. Diamonds represents major decisions taken by all project stakeholders. Each decision node represents a decision model, the complete discussion of which is beyond the scope of this paper.

**DBB Schematic Design Phase:** The Schematic Design phase is presented in three maps. First a traditional DBB process updated from UML to BPMN. Second, level one new BPMN process including preliminary BMR activities. Third, level two new BPMN process including detailed BMR processes. A description of the three maps as follows:

**SD2a - Traditional DBB Schematic Design Process:** Typically, this phase includes developing several preliminary design options or iterations for review and selection of a preferred scheme. Some important activities take place such as: reviewing of the project program with the client, developing spatial relationships, providing preliminary design concepts, obtaining input from the landscape architect, presenting of design concepts to the owner (concept floor plans, sections,



elevations 3D model, etc.), obtaining the owner review and input, and finalizing schematic design deliverables. In addition, a thorough study of zoning and building codes and regulations is much needed

**SD2b - New Schematic Design Process Level 1:** This process starts with identifying all influential aspects of the project design (figure 3). Within this activity, the design team investigates the existing structure on site (if there is one), and identifies its potential for deconstruction, and materials that could be salvaged. Additionally, part of the data gathered for the process includes an identification of available reclaimed materials (including the virtual marketplace), so it can be priced and incorporated into the design. Today, more demands on estimating an accurate project budget by the end of the SD caused primary materials selection to be made early through SD. In addition, design teams are projecting building systems at the end of SD since it is too late to expect systems and material discussions to happen during DD phase. To achieve this, some architectural firms practice in a highly integrated method that allows them to typically meet several times in SD with structural, MEP, civil engineers, landscape architects, etc. therefore, all material choices are being made earlier as they impact updates to cost, thermal performance, etc. BIM has been an efficient medium to achieve this integration.

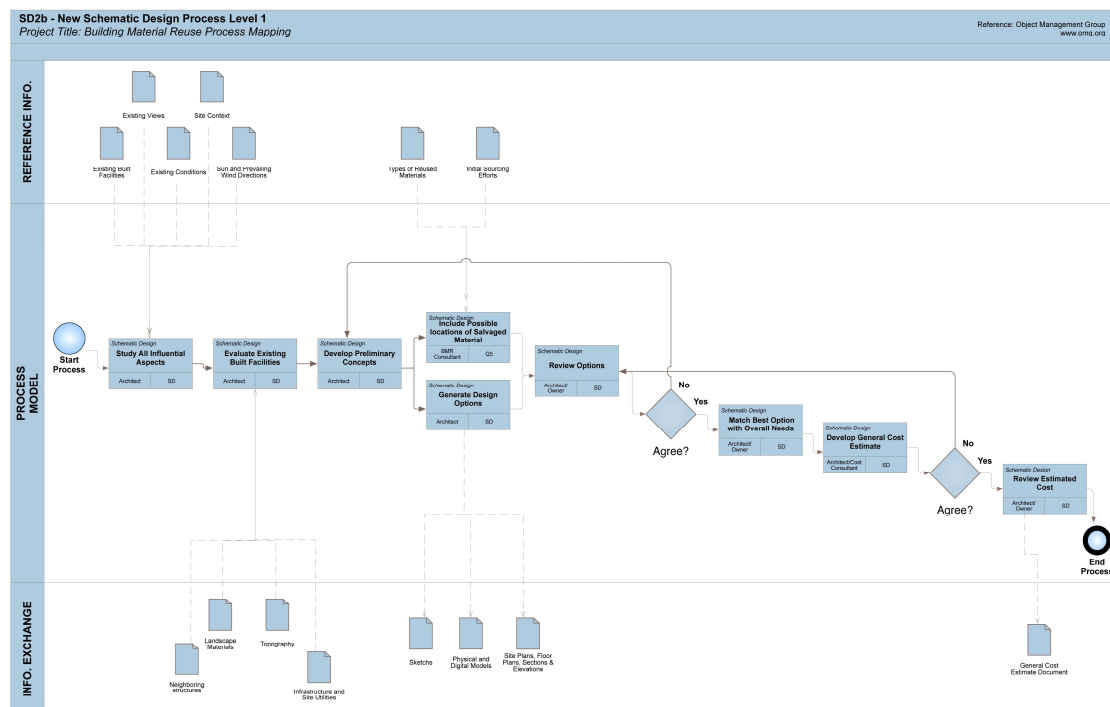


Figure 3: SD2b - New Schematic Design Process Level 1

**SD2c - New Schematic Design Process Level 2:** On a higher detailed level, this process expands on the activities of the previous level. At the information gathering stages, as shown in (figure 4), a list of potential materials from existing buildings on site is generated. To distinguish between functional reuse versus creative reuse, some of the materials are identified as "function-constrained." For example, a set of windows of a particular size would require a specific layout to be reused. Other materials are "function flexible," which can be used as finish materials or

textures, with the expectation that dimensions can be modified as needed (for example, doors used as paneling, lumber used as trim, etc).

During this phase, the design team also brainstorms ideas for detailing material assemblies to allow for future disassembly. Some important information such as historical context as it relates to surroundings, site and region are included at the beginning of the process. This type of information would emphasize the importance of the in-depth knowledge of the social and economic history of the existing buildings. In that regard, and before reviewing the cost with the owner, design alternatives are introduced that may exceed the budget, but add significant value in regards to character and authenticity of the project. Some of the featured activities within the process include: identifying potential material supply for reuse, generating several strategies for material reuse, explaining benefits of reuse to client, and adding to deliverables “target material reuse percentage”.

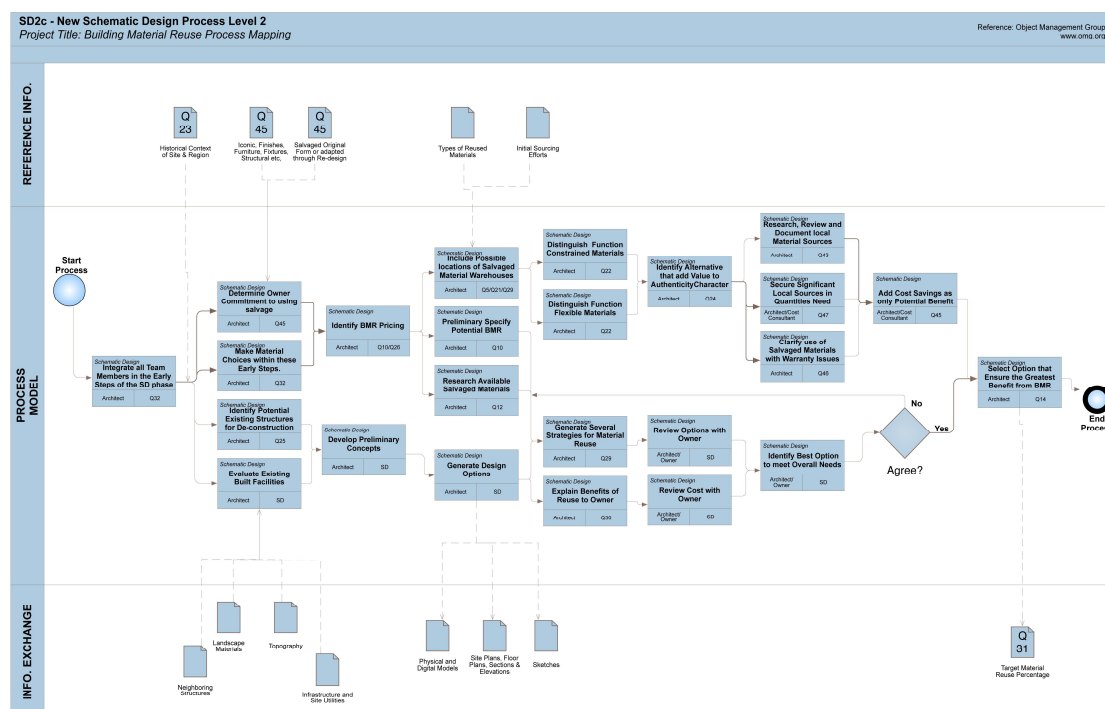


Figure 4: SD2c - New Schematic Design Process Level 2

## 5. Discussion

The work we presented in this paper suggests that design with reuse requires a paradigm shift in the required knowledgebase and the way information flows within the Design-Bid-Build process. Unfortunately, the structure of this paradigm shift is not known and hasn't been well defined. Since knowledge forms the core of building a Decision Support Systems (DSS) for a design team in order to consider reuse, it is necessary to capture the required knowledge and information from the industry experts through a Knowledge Acquisition (KA) process. This knowledge can then be used to 1) identify the building material reuse criteria and 2) to build a prescriptive decision model and 3) to map the process design of the current traditional architectural design workflow and the

proposed one. The overarching goal of this study is to use the building material reuse knowledgebase for 1) building a Unified Virtual Repository database to be connected to all available physical repositories and share a unified standard of information. 2) When the Unified Virtual Repository is integrated with Building Information Modeling (BIM), the DSS can work as a feedback and feed forward support for architects and designers as they consider building material reuse in new designs and constructions. We found that it is essential for a new role to emerge among the project team stakeholders. This role could be labeled as “Reuse Consultant.” Our initial idea was based on giving the architect the ability to make sound decisions on materials and components by providing structured information through the Building Material Reuse Virtual Repository. Architects in the US have already been given more control of the delivery of design to construction managers. The need for an additional stakeholder to join the project team from the early stages is revealed to be critical. The recent emerging businesses like PlanetReuse (a reclaimed construction material broker) are a perfect example. PlanetReuse is making efforts by utilizing technology to build a marketplace platform. InvenQuery is a system currently beta-testing is looking at on-boarding 20-30 stores with plans to put as many of the 1,100+ reuse centers in the US as possible.

## **6. Conclusion**

In this paper we presented the untapped opportunity of streamlining a process of materials exchange between vendors and designers. To map the Building Material Reuse process, three stages of process mapping were essential. First, an overview map which addressed the relationships and the workflow between the different phases of the traditional Design-Bid-Build process and the proposed Building Material Reuse design scenario. Second, a set of detailed process maps that defined and detailed each of six critical phases of the DBB process related to BMR. Each phase of the six phases was detailed in three maps, a traditional process map and two levels of new process maps that were divided into level one and level two. Finally, a set of five strategic maps were developed to synthesize the overall process and to highlight the most important processes within any project delivery method. We only presented an example of transforming the traditional DBB Schematic Design phase into the new two-levels BMR integrated SD phase to illustrate our work. Additional details on our mapping process and the Delphi Knowledge Capturing process will be presented in future studies. The recent development of the US Materials Marketplace is very promising and the global support behind the project only makes us hopeful about the future of the circular economy.

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# **Barriers to On-site Waste Management Innovation in Building Construction Projects**

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## **Abstract**

This conceptual paper provides an early review of literature on on-site waste management innovation to support a proposed research project to investigate barriers seen to constrain adoption decisions in building construction projects. The environmental, economic and social benefits of on-site waste management innovation are discussed; and a proposed integrated framework is presented to establish a starting point for empirical research aimed at exploring the uptake of innovative on-site waste management practice in Australian building construction projects. This paper makes a theoretical contribution to the understanding of project-based organisations within an important empirical setting, namely the Construction and Demolition (C&D) waste management innovation system. Future research by the authors will involve the execution of the proposed research program. Applied outcomes from the proposed research will include the development of effective strategies for industry clients and practitioners to increase levels of on-site C&D waste innovation in building projects.

**Keywords:** Waste, Innovation, Building projects, Sustainable construction

# 1. Introduction

There are formidable challenges associated with resource depletion that require greater attention to reclaiming the embodied energy of existing building stock, and decreasing the energy required to construct new buildings through innovative waste management strategies. To address these challenges, an innovative approach to on-site waste capture and segregation practices is required. This can involve the uptake of on-site processing technology to reduce transport requirements and associated environmental impacts.

Effective product, process and/or system innovation adoption on construction projects can result in improved program performance, decreases in cost and potential improvements in the quality of project outcomes (Rose & Manley, 2012). In response to the challenges of environmental sustainability, global experts have called for greater investment in innovation aimed at reducing whole-of-life building energy consumption, in light of estimates that greenhouse emissions from buildings can be reduced globally by 30% at no net cost, by 2020 (IPCC, 2007). Technological and process advances in on-site separation of C&D waste offer reduced contamination by capturing and segregating materials for effective processing, while on-site re-use through systematic deconstruction techniques enables greater recovery of material resources (Chini & Bruening, 2005).

By identifying the behavioural barriers to adoption of innovative practices, detailed educational interventions can be implemented to improve on-site waste management practice in building projects. Against this background, a large scale research project has been proposed to improve resource and energy efficiency within the Australian building sector, through increased adoption of innovative on-site recycling and re-use of building materials and components in the Construction and Demolition (C&D) waste stream.

This paper is the result of the first stage of the project, involving an early literature review and development of a integrated framework that will be used to guide the first stage of the research, namely: to define the key system participants and activities in the C&D waste management innovation system in the Australian building industry and identify the barriers to on-site waste management innovation. The paper conceptualizes the building construction supply chain as an Open Innovation System, which is extended by applying the adapted Project Based Product Framework (PBPF) to define the C&D waste management context, and proposes Innovation Diffusion Theory (IDT) and Theory of Planned Behaviour (TPB) to explore the decomposed beliefs and behavioural intentions of system participants and subsequent adoption behaviour within this context.

## 2. Innovation in C&D Waste Management

Innovation in on-site separation, processing and re-use of C&D waste offers significant social, economic and environmental benefits over traditional methods, including reduced transportation requirements (Hyder, 2011). Advances in on-site separation can reduce the contamination of building waste by capturing and segregating materials for effective processing, while on-site re-use through systematic deconstruction techniques enables greater recovery of material resources (Chini & Bruening,

2005), thus reducing the embodied energy impact of buildings. In the proposed study, on-site C&D waste management innovation can be categorized into: 1) process and technological innovations in the capture and segregation of C&D waste on-site; 2) advanced fixed or mobile on-site reprocessing technology for material and product reprocessing; or 3) new processes or technology in the on-site re-use of waste materials and components.

Despite research attention in developing strategies to reduce, re-use and recycle C&D waste, implementation of these strategies in practice has been limited (Yuan & Shen, 2011; Tam, 2008). In Australia, the C&D waste stream produces the highest tonnage of waste in comparison to all other waste streams (Municipal Solid Waste and Commercial and Industrial Waste) comprising 18.2 million tons produced nationally in 2010-11 (Hyder, 2011). Of this material, mixed C&D waste represents the majority of waste that is disposed to landfill, emphasizing a need to improve on-site separation/reprocessing and minimize waste contamination (DSEWC, 2012). A recent Australian federal government study (DOE, 2013) pinpointed four key actions required for improvement in recovering resources from the C&D waste stream: (1) Design products and buildings for their eventual deconstruction to enable resource recovery and reduction of embodied energy; (2) Reduce the contamination of waste in the capture and segregation of materials at their source (on-site); (3) Encourage the uptake of recovered materials through improved specifications and knowledge of material and product applications; and (4) Conduct research and development into overcoming market and technical barriers to the uptake of innovative applications. To address these key priorities requires significant change in how C&D waste is re-used and recycled on building sites with particular emphasis on increasing the uptake of innovative practices and technology through behavioural change. Attention is also required to improve the diffusion of C&D waste management best practice across the conservative building industry; seen as a key barrier to uptake (Dampney et al., 2010).

Promotion of construction innovation requires a clear understanding of key organizational barriers constraining uptake. This is particularly relevant to construction project-based organizations that face inherent difficulties in innovative knowledge sharing and benchmarking global best practice (Rose & Manley, 2012). This organizational dynamic has resulted in negative perceptions towards the value of innovation despite persisting regulatory intervention. National and global innovation studies have indicated that regulation should be undertaken alongside policy responses aimed at encouraging more positive attitudes to innovation (OSTP, 2008). Similarly, recent sustainability management research has called for greater emphasis on improving the processes that support the introduction of sustainability technologies, not only to be driven by market demand but also mediated by the vested interests of a wide range of industry stakeholders (Schweber & Leiringer, 2012). By encouraging more positive attitudes towards innovation and addressing underlying problems of conservatism, performance improvement across the construction supply chain can be achieved.

Assuming waste management innovation uptake is centrally driven by key system participant diffusion, the proposed study will map the C&D waste management innovation system and explore the behavioural barriers to the adoption of advanced waste practices, and thus, develop strategies for innovation system improvement within building construction projects. This will build upon the global literature emphasizing the specific need for further research into understanding practitioner attitudes towards C&D waste re-use and recycling (Yuan & Shen, 2011; Teo & Loosemore, 2001). As a starting



point, this paper proposes a novel theoretical frame where the building supply chain is conceptualised as an Open Innovation System, which is extended by applying the adapted Project Based Product Framework to define the C&D waste management context, and integrates IDT and TPB to explore the decomposed beliefs and behavioural intentions of key system participants.

### **3. Integrated Framework**

The proposed integrated framework shown at Figure 1 takes a different approach to the common construction innovation models currently offered, with emphasis on system-wide analysis of project-based innovation within the Project-Based Open Innovation System (PBOIS). Existing models have tended to focus on a firm-level innovation management that has lacked explanatory power when dealing with the complexities of the traditionally fragmented project-based construction supply chain (Hartmann, 2006), with an emphasis on the relationships and interdependencies in the built environment product system. Indeed, the project-based nature of production in the construction sector creates unique challenges to the adoption of innovation, compared to say, the manufacturing sector, for example. The temporary nature of teams makes it difficult to build up the strength of relationships often needed for successful innovation. In addition, the project to project production method implies a discontinuity which makes the accumulation of knowledge within project based firms difficult. The regulatory and institutional context shapes, and is shaped by, the supply network, project-based firms and projects, with the technical support infrastructure playing a similar role.

This exploratory paper of on-site waste management innovation is based on an international review of peer reviewed journals and industry reports to support proposed empirical research aimed at investigating barriers seen to constrain adoption decisions in building construction projects. It draws on highly cited articles and industry reports published between 1985 and 2013. The articles dealt with the adoption of waste management innovation in Australia. Content analysis was employed to define waste management innovation in view of the integrated framework, shown in Figure 1. The authors each independently allocated the themes arising in the literature to the activities and actors shown in Figure 1. Following this, the two sets of analysis were merged and triangulated to arrive at a consensus understanding of the nature of on-site waste management innovation as a foundation to the proposed empirical work.

The paper draws upon previous work in the application of Open Innovation Systems in complex project-based environments (see Rose & Manley, 2012) and focuses on a specific type of project-based innovation from an integrated system perspective, contextually tailored to the unique vertical and horizontal supply chain relationships within this system (e.g. inclusion of the waste reprocessing firms as a potentially critical knowledge link across project organisational boundaries). Further, drawing for the first time upon the integration of Innovation Diffusion Theory (IDT) and Theory of Planned Behaviour (TPB) as a lens to interpret the decision-making of project-based construction organisations in the PBOIS, the proposed study will result in a deeper and more finely-grained understanding of the barriers to building innovation across complex supply chains than is currently possible with existing approaches.

Gann and Salter's (2000) seminal Project-Based Product Framework (PBPF) is adapted and treated as an Open Innovation System (OIS) (Gassmann, 2006; Rothwell, 1994) to provide context for our study. This adaption takes into account for the key players and dynamics associated with waste management. The relationships between stakeholders and their reliance on one another are emphasised to source external ideas for innovation. The open innovation knowledge links are represented as arrows in the model. This extended framework provides a rich context in order to interpret and assess the beliefs and behavioural intentions of organisations within a project-based open innovation system. C&D waste reprocessing firms are uniquely positioned in the PBOIS; these manufacturing-based organisations interact with project-based organisations (e.g. contractors and consultants) at both the end of a building lifecycle i.e. at demolition stage (purchasing sorted C&D waste) and in design and construction stages (sale and integration of recycled materials/products). The inclusion of the C&D waste reprocessing firms adds an additional dimension to the innovation system, as they potentially act as key knowledge brokers in the diffusion of C&D waste management innovation in both design/construction and demolition/disposal stages.

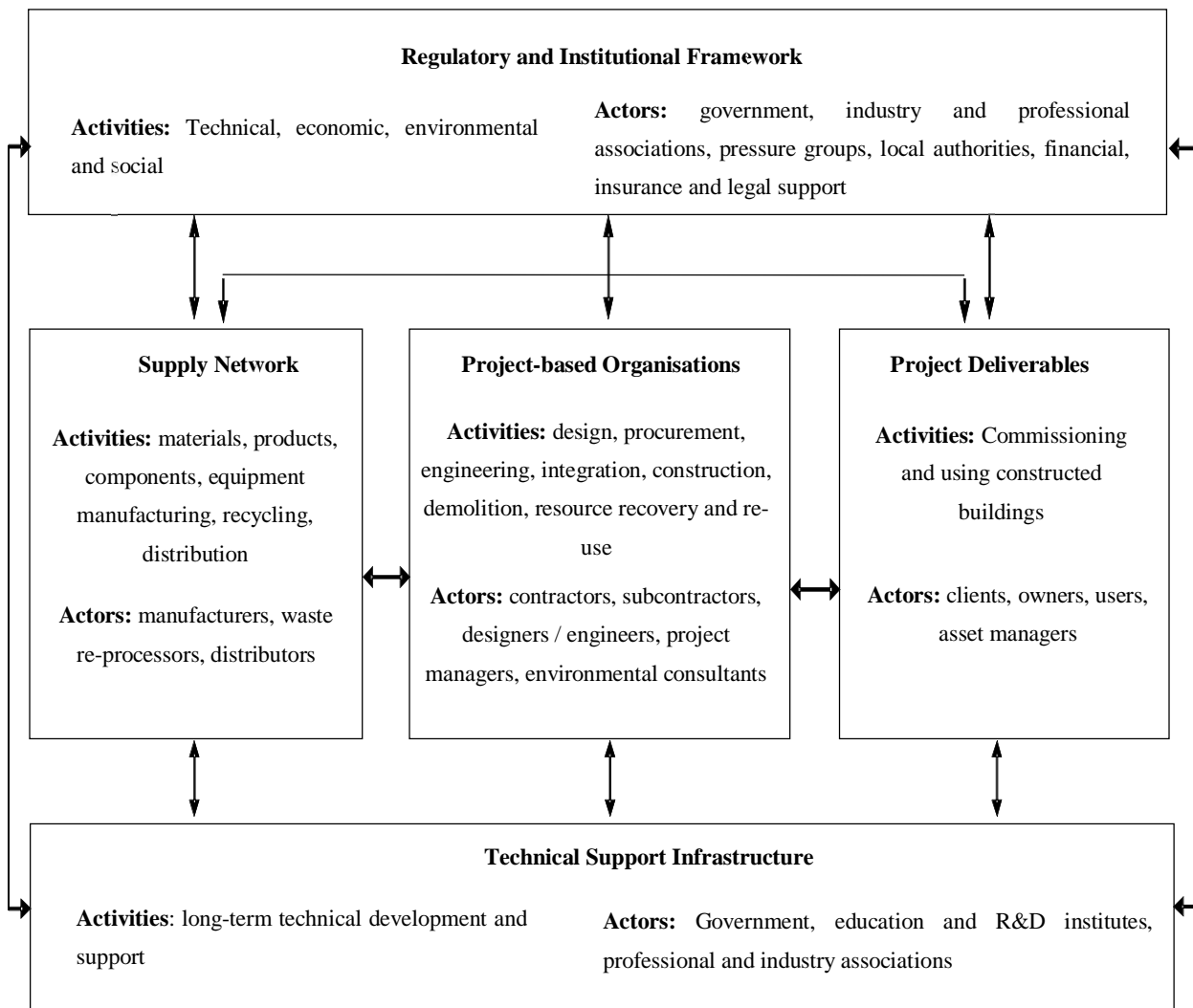


Figure 1: Project Based Open Innovation System (PBOIS), based on Gann and Salter (2000)

Further, to interpret the beliefs and behavioural intentions of project-based organizations within the C&D waste management innovation system, the two key behavioural decision-making theories; TPB and IDT, are integrated. Variations of this integrated IDT/TPB model have been applied to explore user intentions to adopt technology in the area of information technology (Shih & Fang, 2004) and marketing (Taylor & Todd, 1995). This is the first time it will be applied in the context of a project-based environment as defined by the extended PBOIS. The integrated IDT/TPB model is shown at Figure 2.

TPB is a well-known behavioural theory that hypothesizes actual behaviour as a direct function of behavioural intention, as the weighted sum of attitudes, subjective norm and perceived behavioural control (Ajzen, 1985). TPB is one of the most influential and commonly employed theories to explain intentions to use new technology (Mathieson, 1991). Despite the usefulness of TPB as a foundation theory to explain behavioural intentions of construction practitioners (Teo & Loosemore, 2001), it is contended that a decomposition of attitudinal drivers is required to better understand the relationship between antecedents of intention and relationship between attitudinal structures towards innovation adoption (Taylor & Todd, 1995). Thus, key innovation characteristics that influence adoption attitudes drawn from IDT (Rogers, 2003), are integrated and combined with TPB to improve its explanatory power within an innovation system context.

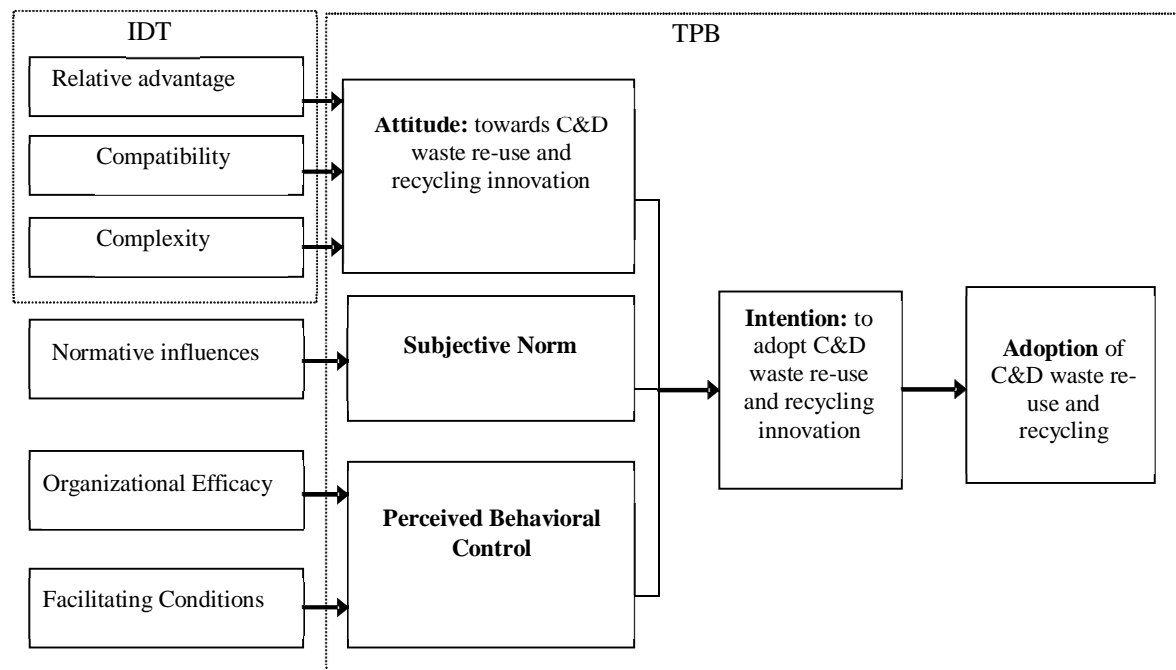


Figure 2: Innovation Diffusion Theory (IDT) and Theory of Planned Behaviour (TPB), based on Shih & Fang, (2004)

In summary, the model proposes IDT (innovation specific) contributes to the broader TPB constructs where IDT can usefully be integrated to inform the antecedents of potential adopter *attitudes*. According to the model, behavioural intention is then a function of attitude, subjective norm and perceived behavioural control. The actual behaviour of project-based stakeholders to adopt innovation is a direct function of this behavioural intention. According to the integrated IDT/TPB framework, it is predicted

that to increase adoption of on-site C&D waste management innovation, project-based organizational managers (as the decision-makers in this context) need to have a positive attitude towards the innovation, perceive support from individuals and groups around them; and control over the adoption process and outcome. It is expected by mapping C&D waste management innovation via system-wide analysis within the Project-Based Open Innovation System (PBOIS) will provide a more finely graded interpretation of the behavioural barriers constraining adoption across the innovation system.

#### **4. Mapping of the on-site C&D waste management innovation system and adoption behaviour**

Drawing upon the theoretical frame, the empirical stage of the research will aim to define the key system participants and activities in the C&D waste management innovation system in the Australian building industry. This research component will comprise an inductive semi-structured interview program. Semi-structured interviews will be conducted with selected representatives across six key sectors involved in the C&D waste management stream: (1) clients, (2) managing contractors, (3) subcontractors, (4) consultants, (5) waste re-processers and (6) material manufacturers. Interviewees across these six key sectors will be purposefully selected based on their level of experience and understanding of C&D waste management practice in the building construction industry. It is envisioned a total of 60 interviews will be conducted, with ten from each sector as recommended (Eisenhardt, 1989). The interviews will elicit salient perceptions of on-site C&D waste management behaviour (including adoption barriers) and define the relationships across stakeholders in the supply chain, as conceptualised in Figure 1. Key industry bodies will be recruited as research supporters through extensive researcher networks (including access to leaders of national construction industry associations) to assist in the identification of suitable interviewees.

Taking an integrated, non-linear view of the supply chain allow researchers to draw rich data about individual sector perspectives, and triangulate perspectives on innovation adoption behaviour across the six industry-stratified sectors. This stage will reveal knowledge gaps and policy shortcomings that currently constrain the uptake of innovation. A qualitative approach is proposed in order to explore in-depth the complex relationships and interdependencies within the innovation system. Access to a rich data set during the formative stages of the project will provide the foundations for the development of a valid and robust model. Although the sample will be enlarged if required via a snowball sampling method, it is anticipated 'data saturation' will occur with this sample size. Content analysis will be used to code the interview transcripts; NVivo software to classify, sort and arrange the data; and comparative techniques to draw out the most influential factors.

The proposed empirical work will derive focused innovation system data within the context of a specific innovation type at project organisational level. Drawing on the innovation system dynamics and current adoption activity data, it is envisioned a quantitative survey will then be undertaken to identify the most important predictors to the intention to adopt on-site waste management innovation by project-based organisations in the building construction industry.

## 5. Conclusions

Current waste volumes from Australian construction projects have reached concerning levels, with 6.25 million tons of C&D waste buried in landfill in 2013. Similarly, the embodied energy in the existing Australian building stock is equivalent to ten years of national energy consumption, reflecting the significance of innovation in the recovery of resources at building end-of-life (DSEWC, 2012). Compared to conventional C&D waste disposal methods, there is the potential for greater than 90% of building recycling to be routinely achieved if supply chain organizations give priority to waste recycling measures (Dampney et al., 2010). However, advanced waste recycling and re-use practices on construction projects remain low (Yuan & Shen, 2011). It is argued that comprehensive research is required into how practitioner attitudes influence C&D waste management behaviour from an integrated innovation system perspective.

The proposed research presented in this paper will build upon previous research in seeking to understand practitioner attitudes towards C&D waste re-use and recycling, and for the first time, proposes an integrated framework to explain on-site C&D waste management behaviour through an innovation system lens. It will focus on the beliefs and behavioural intentions of project-based organisations as the key actors in the adoption of on-site C&D waste management innovation. Although the focus is on project-based organisations, we also will explore the roles and influences of the supply network (e.g. manufacturers and waste re-processors), building clients and end users, the technical support infrastructure (e.g. research and development) and the regulatory and institutional framework (e.g. state and local government regulators) on innovation adoption decisions.

Although the framework is yet to be validated through empirical research; it is anticipated that the results from the future empirical work will shed new light on the innovation system supporting the adoption of innovative on-site waste management initiatives. Nevertheless, it currently provides a solid foundation for future research within this innovation area. Applied outcomes from the proposed research will include the development of effective strategies for industry clients and practitioners to increase levels of on-site C&D waste innovation resulting in positive environmental, social and economic outcomes.

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# Who should be leading in the process of successful SCM implementation in construction?

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## Abstract

Despite the critical role of a client in enabling supply chain integration, parties on the supply side of the construction supply chain – the lower tiers of the construction supply chain – are believed to be able to develop into more integrated production systems, independently from the demand. Main contractors are acknowledged to have a central position in the management of supply chains, offering great potential in the effective integration of their supply chains. This is deemed to be necessary as construction supply chains are fragmented, complex, highly uncertain and with many stakeholders requiring a leading actor to coordinate the process and relationships – projects are characterised by a high supplier involvement. This study sets out to explore the differences between the organisations involved at the lower tiers of the construction supply chain, focusing specifically on the internal SCM organisation of main contractor and supplier organisations, and their direct inter-relationships. SC Maturity levels are formulated according to relevant SCM concepts and based on Holti et al.'s (2000) seven principles of SCM organisation, and used to examine the relative SC Maturity of eight large main contractor and supplier organisations within the context of the Dutch construction industry. A case study, representing a construction supply chain initiated by a main contractor as a result of ongoing poor financial performance during the economic crisis and the existence of high failure costs, is further investigated to examine the SC Maturity levels based on one of the principles in more detail. This way the paper starts a discussion towards the development of an improvement framework and brings up the need for a more mature supply chain integrator, an organisation leading in the process of SCM implementation.

**Keywords:** SCM, Supply Chain Maturity, main contractor-supplier collaboration, construction supply chain, leadership.

## 1. Introduction

The construction industry is widely criticised for adopting highly adversarial and fragmented approaches to relationships, where design is separated from production and there is a lack of suppliers' involvement at the early stages of projects (Egan, 1998; Bresnen & Marshall, 2000; Chan et al., 2003). Although fragmentation originally occurred in response to highly variable workloads and subcontracting developed as a flexible way of dealing with these, it has resulted in complex contractual relationships and discontinuity of teams (Fulford & Standing, 2014). Several studies have underlined the need for radically different approaches to supply chain relationships that achieve 'customer delight' and minimise turbulence in stakeholders' relationships (Latham, 1994; Cox & Ireland, 2002; Pryke, 2009) and there has been a move towards better supply chain integration, and the formation of strategic partnerships and collaborative agreements between supply chain actors since (Akintoye et al., 2000; Holti et al., 2000; Briscoe & Dainty, 2005; Rimmer, 2009).



As part of this movement, the search for new and more integrated approaches to the construction supply chain has taken on a renewed importance for many organisations operating within the wider construction industry (DTI, 2003; Holti et al., 2000), also in the Netherlands, following the large number of recommendations in PEC's final report (2003) and following the British vision on collaboration as described in 'Rethinking Construction' (Egan, 1998). At the lower tiers of the construction supply chain, the supply side, however, there remains a paucity of properly documented examples of successfully implemented Supply Chain Management (SCM) initiatives (Cox & Ireland, 2002; Aloini et al., 2012). Construction projects are characterised by a high supplier involvement and rely heavily on subcontracting (Mbachu, 2008). Subcontracting has been adopted as the dominant procurement strategy as a consequence of the uncertainty faced by main contractors in obtaining continuous work and the need to accommodate the different, increasingly specialised and complex, requirements of each project (Tam et al., 2011). The low levels of repetition increase the unpredictability of the flow of work (Vrijhoef, 2011). Major developments, such as the increased use of integrated contracts, have resulted in a shift of responsibilities from client to main contractor. A consequence of this increased responsibility is that main contractors require capabilities and knowledge which do not belong to their own core competences and need to be purchased from suppliers (Bemelmans et al., 2012) – main contractors increasingly depend on their suppliers, both for realising projects and for achieving the required performance in these projects (Bemelmans et al., 2012). The term suppliers covers subcontractors, material suppliers and service suppliers.

While several studies underlined the importance of main contractor-supplier collaboration (Kale & Arditi, 2001; Cao & Zhang, 2011; White & Marasini, 2014), there appears to be a belief that existing SCM initiatives are adopted by contractors in order to increase their profitability at the expense of other members of the supply chain (Dainty et al., 2001). The increasing percentage of project turnover which is spent on buying goods and services does provide opportunities for collaboration and emphasises the importance and significance of managing suppliers (Bemelmans et al., 2012). Contractors are willing to develop closer relationships (Ross & Goulding, 2007), but implementing SCM seems a long-term, complex process and requires a certain level of understanding and therefore learning throughout the supply chain. SCM also questions the functional structure of many organisations as these can impede effective collaboration internally and subsequently collaboration with its direct suppliers (Van Weele, 2008).

This study sets out to explore the differences between the organisations involved at the lower tiers of the construction supply chain, focusing specifically on the internal SCM organisation of main contractor and supplier organisations, and their direct inter-relationships (Broft, 2012; Pryke et al., 2014; Broft et al., 2016). SC Maturity levels are formulated according to relevant SCM concepts and based on Holti et al.'s (2000) seven principles of SCM organisation, and used to examine the relative SC Maturity of eight large main contractor and supplier organisations within the context of the Dutch construction industry (Broft, 2012; Pryke et al., 2014; Broft et al., 2016). A case study, representing a construction supply chain initiated by a main contractor, is further investigated to examine the SC Maturity based on one of the principles in more detail. This way the paper starts a discussion towards the development of an improvement framework and brings up the need for a more mature supply chain integrator, an organisation leading in the process of SCM implementation.

## **2. Conceptual development**

### **2.1 Supply chain relationships in construction**

Construction is a complex systems industry, managed through projects involving multiple, temporary, and transient organisations (Kumaraswamy et al., 2005; Pryke, 2012). The largely sequential approach typically supports a lack of integration between design, construction and maintenance methods, leading to inefficiencies, inferior value and poor margins (Holti et al., 2000).

A supply chain is described by Christopher (2005, p.17) as “a network of organisations that are involved, through upstream and downstream linkages, in the different processes and activities that produce value in the form of products and services in the hands of the ultimate consumer”. Attention is nowadays focussed on ensuring competitive advantage for the integrated supply chain (Green et al., 2005) – businesses no longer compete as a sole business entity, but rather in a ‘supply chain versus supply chain’ manner (Lambert & Cooper, 2000; King & Pitt, 2009). In construction, a supply chain is characterised as (Vrijhoef & Koskela, 2000):

- § Converging at the construction site – the object is assembled from incoming materials and through different services;
- § Temporary – one-off construction projects are produced through repeated reconfiguration of project organisations; and
- § A typical make-to-order supply chain – every project creates a new product or prototype.

These characteristics are often seen as peculiarities of the industry and prevent the attainment of flows as efficient as in manufacturing (Koskela, 1992). The relationships required for the delivery of the constructed product among main contractors and suppliers are often weak and difficult to manage (King & Pitt, 2009). This is largely as a result of the fragmented nature of the industry and its notorious dependence on subcontracting and competitive pricing (Morledge et al., 2009) – the management of the discontinuous exchanges in project-based industries is problematic due to the discontinuity of demand for projects, the uniqueness of each project in technical, financial and socio-political terms, and the complexity of each project in terms of the number of actors involved (Skaates et al., 2002; CrepsinMazet & Ghauri, 2007).

Rapid technological development in both products and services has driven main contractors to adopt outsourcing strategies involving external suppliers rather than develop in-house capabilities (Cox & Ireland, 2002; Green et al., 2005). The main contractor, the principal construction organisation that manages a construction project, executes only a small part of the product by its own personnel and its own production facilities (Dubois & Gadde, 2000). The low barriers to entry, proven by the large amount of small and medium-sized construction-related enterprises, is a characteristic of the industry that encourages fragmentation (King & Pitt, 2009). Competitive pricing is also promoted through procurement strategies often pursued by clients, such as design-and-build, which favours the lowest bidder (RICS, 2006). As a result of the industry’s fragmentation and prevalent competitive tendering, relationships are often opportunistic with main contractors competing to win work through competitive pricing whilst reducing the quality of the end product in order to improve profit margins (King & Pitt, 2009). The consequences are poor production processes, limited ability or willingness to innovate due to lack of investment, late project delivery and budget overrun (Morledge et al., 2009). Fragmentation however, must not be seen as strictly problematic. The involvement of many different specialised firms in projects does not necessarily cause low levels of efficiency. On the contrary, it has been claimed that this could just as well increase the efficiency of resource allocation and speed of information exchange between parties (Pryke, 2002).

The ability to build collaborative relationships is also hindered by the prevalent adversarial relationships brought in by opportunism, lack of trust and inequitable allocation of risk. While suppliers are often regarded as individualistic and only motivated by profit, contractors are viewed as opportunistic when it comes to winning bids, usually transferring risk to the lower tiers of the supply chain (Cox & Ireland, 2002). More often than not, it is clients rather than main contractors that take the initiative towards building good relationships with their supply chain.

## **2.2 An integrator of the construction supply chain**

Intense and often global competition, high technological standards and rapidly changing market demands have pressed manufacturing industries to manage processes throughout the supply chain in an

effective and efficient way (Cagliano et al., 2006). The high levels of alignment and repetition within these supply chains have led to highly productive and fast operating strategic coalitions of firms (Kirche et al., 2005; Zailani & Rajagopal, 2005; Kim, 2006). The construction industry on the contrary, knows two typical problems resulting from high levels of fragmentation and low levels of repetition: lack of control and decreasing performance – the industry supposedly shows low levels of performance and backwardness in many respects (Woudhuysen & Abley, 2004) – which tend to reinforce each other throughout the supply chain because of causal relationships within the supply chain (Pryke, 2002). The main objective of SCM is to enhance mutual competitive advantage and this can be achieved through improved relationships, integrated processes and increased customer focus (Pryke, 2009).

For this reason, the interest in adopting SCM techniques has been growing in the construction industry since the 1980s (Segerstedt & Olofsson, 2010), but many applications of SCM in construction have been limited to the management of construction materials and long-term arrangements with suppliers (Vrijhoef, 2011). One of the supply chain principles from manufacturing that could be reconceptualised and applied to the specific context of construction (Vrijhoef, 2011) includes the introduction of the role of the supply chain integrator in the supply chain – one of the critical phenomena lacking in the construction industry is the recognition of a generally accepted focal company initiating the integration of the supply chain. This focal company coordinates and ties together all flows through the supply chain as if it were an extended enterprise (Figure 1).

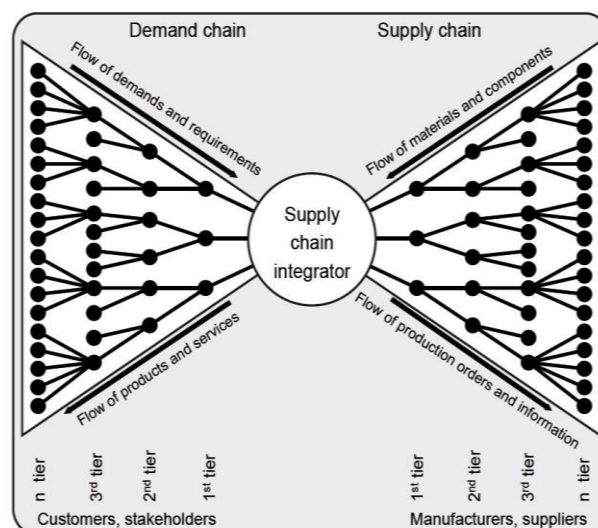


Figure 1: Supply Chain Integrator (Segerstedt & Olofsson, 2010, pp. 349; Vrijhoef & De Ridder, 2005).

Holti et al. (2000) do offer an approach to managing supply chains in which they recommend single point responsibility to the client and describe a collaborative model of overall leadership in achieving value for money, to effectively integrate supply chains. This integration knows two complementary senses: At project level – an integrated supply chain requires a productive balance of leadership of both the design and the construction or delivery processes – and over time across projects (Holti et al., 2000). This is deemed to be necessary as construction supply chains are fragmented, complex, highly uncertain and with many stakeholders, requiring a leading actor to coordinate the process and relationships (Holti et al., 2000). One of the other main concepts however, is that all supply chain partners have the potential to contribute to the aggregation of value (Holti et al., 2000) – all supply chain actors need to be able to make a full contribution to ensure that the client's needs are fulfilled and that value creation is maximised. The client and chosen procurement method are both critical in enabling supply chain integration and project-independent construction. However, independently from the demand, parties at the supply side may evolve towards more integrated production and business formats, through

project-independent collaboration with other parties in the supply chain as well as internalisation of neighbouring activities or businesses (Vrijhoef & De Ridder, 2005).

Pryke (2009) acknowledged the central position that main contractors play in the management of supply chains, offering great potential in this leading role. It is believed that main contractors have more influence on the organisation of the project and on the performance and quality of the work of its suppliers (Latham, 1994). Despite the fact that they have such an important role in channelling client demand through their own supply chains, main contractors are overlooked when it comes to research and useful advice (King & Pitt, 2009). Moreover, implementation of SCM by main contractors is relatively slow (Green et al., 2005) as SCM is often seen as a project-specific approach in construction rather than a central strategy such as in industries like aerospace and car manufacturing (Green et al., 2005; Womack et al., 2007). In addition, within a main contractor's organisation, the management function is typically disconnected from the production function on site as if it were two separate organisations: "one for the management function and one for getting the work done. The two organisations do not coordinate their work, and they are characterised by different goals and viewpoints" (Applebaum, 1982).

### **2.3 Towards SC Maturity in construction**

SCM is a new way of thinking about management and processes, in order to coordinate supply chains more efficiently, by managing the associated relationships to deliver customer value, through innovation and continuous improvement (Cooper & Ellram, 1993; Christopher, 2005; Pryke, 2009; Blanchard, 2010; Fulford & Standing, 2014). It can be categorised into four different levels (Harland, 1996):

1. The management of an internal supply chain integrating the activities of a firm;
2. The management of a dyadic relationship between two immediately connected suppliers;
3. The management of a chain of businesses with which a firm has no contractual relationship; and
4. The management of a network of interconnected businesses involved in the ultimate provision of a product to customers.

The management of the different levels is necessary as they form an integral part within a greater context: the supply network. Dainty et al. (2001) and Pryke (2009) describe SCM in construction as the management of the network of relationships within which firms are embedded. A holistic view is required for each of these levels to ultimately contribute to performance improvement and customer delight within the industry (Pryke, 2009). This contribution is fundamental in the creation of competitive advantage, which reflects the influence of efficient and constructive network relationships on a firm's short-term financial position and long-term competitive power (King & Pitt, 2009; Van Weele, 2010).

Holti et al.'s approach (2000) involves essential ingredients for a construction company (level 1) to function in a SCM-driven environment (Figure 2), described as seven principles. The first principle 'Compete through superior underlying value' is concerned with enhancing the value of what is actually delivered by improving quality and reducing underlying costs. Members of the construction supply chain use their capabilities to collaboratively take the 'right' costs out in order to achieve competitive prices and mutual benefit. This requires a good understanding of the client's perception of value, in principle defined as a combination of a lower price and higher quality, and insight into cost components, the protection of margins, and the elimination of waste and inefficiency. This main principle depends on embracing the other six as a mutually reinforcing set. 'Define client values', the second principle, involves a more rigorous way of value assessment – client value being defined as a built-up and clarification of the functional requirements, the design character and the target through-life cost (TLC) profile for the desired building. The third principle 'Establish supplier relationships' encompasses commitment to forming long-term relationships with a small number of suppliers in each key supply category around major and core-business, still allowing variety and flexibility for varying types of projects in varying regions. Essential are the project-independent characteristics and the need of

commonly identified and clear business goals for the overall supply chain at the outset. ‘Integrate project activities’ is the fourth principle and describes a mechanism for the choice of strategic long-term partners through which effective management of the partners that collaborate on a project can be achieved. The goal is to resolve all design-related issues at key interfaces at an early stage by creating clusters and use concurrent engineering, with specialist suppliers involved early in the process to create commitment to subsequent phases. The fifth principle ‘Manage costs collaboratively’ employs a unique approach to dealing with and optimising costs, referred to as ‘target costing’, where suppliers work backwards from the client’s functional requirements and the maximum market price for the item. Margins are then disengaged from risk allowances and costs through ring-fencing, providing the security to look at underlying costs. ‘Develop continuous improvement’ is the sixth principle aiming to achieve decreasing prices and/or improving functionality and value for future projects. It is a vehicle for achieving longterm performance improvement that cannot be achieved over the life of one project and therefore, involves agreed long-term relationships where component and process costs are continuously reduced through systematic planning and process improvement. Lean principles and kaizen events are made a regular, reliable and long-lasting occurrence by taking control of the supply chain (Blanchard, 2010).

‘Mobilise and develop people’, the final principle, responds to the substantial cultural change needed in the construction industry in order to successfully implement SCM. This includes the mobilisation and development of employees through four key mechanisms: a visible, systematic commitment from the top, the facilitation for project teams, training in new skills and economic incentives.



*Figure 2: The seven underlying principles (Holti et al., 2000).*

The seven principles outlined above demonstrate that implementing SCM encompasses the recognition of essential SCM elements internally, within an organisation. The aim of this study is to outline the differences in SC Maturity of main contractor and supplier organisations, and to underline the need for greater degree of main contractor leadership, in order to improve the internal organisation of both types of firms, and subsequently achieve greater collaboration between them.

### **3. Research method**

Given the exploratory nature of the study, a qualitative approach was considered the best-suited for this research (Blumberg et al., 2011). Data collection was largely based on primary data, which, building on Yin (2014), was gathered from semi-structured interviews with representatives from main contractor and supplier organisations.

From an earlier pilot study (Broft, 2012; Pryke et al., 2014; Broft et al., 2016), it was evident that the companies involved in the study had several uncertainties regarding their own and their partner's position and role in an effective SCM collaboration. It seems that most barriers in the relationship flow from these uncertainties and that supply chain integration cannot be established when the parties involved are not integrated themselves. Therefore the conclusion was drawn that it would be beneficial to give the companies a system of self-evaluation as an indicator of SC Maturity and feedback to enable them to integrate internally and thus facilitate gradual and meaningful implementation of SCM within the entire chain (Broft, 2012; Pryke et al., 2014; Broft et al., 2016).

The first part of the main study thus focused on the analysis of the current SCM status of all individual companies involved (Broft, 2012; Pryke et al., 2014; Broft et al., 2016) – four large main contractors and four larger suppliers, operating in the Dutch construction industry, were included in this research. The participating companies, like most other European firms, had been confronted with a difficult economic climate, during the period of this research, characterised by increasing competitive pressures and profit demands. The research was limited to the managerial level of the companies and involved respondents with the responsibility of implementing SCM. Table 1 provides an overview of the participating companies and representatives.

*Table 1: Overview of organisations involved.*

<b>MAIN CONTRACTORS</b>			
<b>Name</b>	<b>Position</b>	<b>Company</b>	<b>Company Profile</b>
Interviewee 01	(Ex-)Director Purchasing	Organisation 01 (BN)	Construction, development, infrastructure, services and specialist activities.
Interviewee 02	Director Purchasing	Organisation 02 (BM)	Construction, mechanical/electrical services, civil engineering, property, PPP.
Interviewee 03	Director	Organisation 03 (DV)	Construction, real estate and infrastructure.
Interviewee 04	Director	Organisation 04 (WB)	Housing, social/commercial properties, and renovation.

<b>SUPPLIERS</b>			
<b>Name</b>	<b>Position</b>	<b>Company</b>	<b>Company Profile</b>
Interviewee 05	General Director	Organisation 05 (GV)	Supplier/manufacturer of aluminium windows, facades, doors and blinds.
Interviewee 06	Business Leader	Organisation 06 (GB)	Precast concrete floor systems and other concrete construction elements.
Interviewee 07	Director	Organisation 07 (TV)	Plumbing and sanitary installation company.
Interviewee 08	General Director	Organisation 08 (BV)	Manufacturer of the interior door/frame package.

The themes and accompanying questions for this analysis were derived from the seven principles, described in Section 2.3. Maturity levels were developed after the interviews were held with the highest maturity level representing the ideal elements of an SCM organisation according to Holti et al. (2000). Jointly, the current score provides a relative comparison of SC Maturity among participating companies rather than an absolute measure. This relative comparison is used to differentiate between SCM elements, and to compare the two different types of companies and relate this comparison to the different role perspectives. Section 4.1 and 4.2 include a description of the findings.

The leading role of main contractors is further investigated in a case study, the second part of the research, in which a main contractor decides to form long-term agreements with thirteen suppliers in its key supply categories. This main contractor believes in collaboration and initiates the integration of its supply chain. The study then examines the maturity of all supply chain actors involved at the start of their collaboration based on the most important principle (Section 2.4). The themes around Principle 1 include insight into cost components, margins and the level of waste (Holti et al., 2000). Again, the two different types of companies are compared – research is extended to project/site level. Table 2 provides an overview, including some basic facts, of the fourteen supply chain actors.

*Table 2: Overview of organisations involved in case study (facts based on 2015).*

	Discipline	Location (region)	Turn-over	Amount of employees				
			Total	Total	Fixed	Flex.	Office	Site
Contractor T	Main contracting	Utrecht/Overijssel	188 mln.	258; 65	60	5	35	30
Supplier T1	Finishing	Overijssel	15 mln.	125	95	30	25	100
Supplier T2	Plastering & Finishing	Zuid-Holland	15 mln.	150	40	110	20	130
Supplier T3	Timber structures	Groningen	-	89	58	31	23	68
Supplier T4	Concrete contractor	Friesland	53 mln.	209	186	41	57	152
Supplier T5	Finishing	Overijssel	26 mln.	300	100	200	25	275
Supplier T6	Production of precast concrete	Friesland	21.1 mln.	80.8	65.4	15.4	19.2	61.6
Supplier T7	Production of doors	Gelderland	38.3 mln.	157	-	-	45	112
Supplier T8	Tiling	Overijssel	35 mln.	58	28	30	4	54
Supplier T9	Production of wooden frames	Friesland	5.5 mln.	38	25	13	8	30
Supplier T10	Contractor of storages	Overijssel	137 mln.	243	243	-	-	110
Supplier T11	Tiling	Noord-Holland	7.5 mln.	45	-	-	4	41
Supplier T12	Installation technology	Overijssel	59 mln.	513	347	166	-	409
Supplier T13	Production of carpentry	Gelderland	17 mln.	119	95	24	34	85

## 4. Research findings

This section presents the research findings. It should be noted that the research findings have limitations presented by the chosen research methodology. The findings concern only a limited amount of main contractor and supplier organisations and need to be tested using quantitative research in order to be representative of the industry.

### 4.1 The relative SC Maturity of eight construction companies

The analysis of the research findings is based on the developed SC Maturity levels. Emphasis is placed on the current characteristics of the organisation and its level in implementing important SCM elements. The scores achieved in relation to the themes are summarised in Table 3. The individual ratings as shown in this table mirror the status of each participating organisation against Holti et al.'s (2000) ideal SCM organisation. The table shows scores that range between 0 and 3, and just occasionally reach higher than 3, for both main contractors and suppliers. As set out in Section 2, the construction industry is known to be a challenging industry for SCM implementation (Aloini et al., 2012).

The ratings achieved for Principle 1, 5 and 6 are the lowest across the seven principles. Principle 1 ‘Compete through superior value’ requires insight into the build-up of costs and clarity about ‘right’ and ‘false’ costs, however, this clarity seems to be missing – “*The construction world is familiar with the concept of failure costs, but nobody knows how high these costs are or even what the real definition involves*” (Interviewee 02, BM). Findings in relation to Principle 5 ‘Manage costs collaboratively’ reflect practices that favour short-term financial gains, such as non-legitimate risk transfer, contradicting SCM. Principle 6 ‘Develop continuous improvement’ was found to be well-understood, however doubts exist on how to correctly implement it in a project-environment. Some of the issues raised by interviewees were the difficulty of applying project-specific knowledge to other types of projects (Interviewee 01, BN) and the fact that knowledge often resides with people (Interviewee 07, TV).

Table 3: Overview of the themes and SC Maturity ratings.

	BN	BM	DV	WB	GV	GB	TV	BV
<b>General</b>								
Insight into the construction supply chain	0	2	2	2	0 / 1	1 / 2	3 / 4	3 / 4
<b>Principle 1: Compete through superior value</b>								
Insight into profit/turnover level	0	1	2	0	0 / 1	0 / 1	2	2 / 3
Value adding activities and wastage	-	0	2	2	1	1	2	2 / 3
<b>Principle 2: Define client values</b>								
Client's wishes and specifications	0 / 1	2 / 3	3	1 / 2	1 / 2	1	3 / 4	1
Customer delight	1	2	3	3	1	3 / 4	3	3
<b>Principle 3: Establish supplier relationships</b>								
Black box of subcontracting	0	1	1	3	1 / 2	1 / 2	2	2 / 3
Strategic partners	0	3	1	2	1	2	3	3
<b>Principle 4: Integrate project activities</b>								
Partner involvement	1	1	1 / 2	2	1 / 2	2 / 3	2 / 3	2
Integration of processes	0	0	2 / 3	2 / 3	1 / 2	2	2	2
<b>Principle 5: Manage costs collaboratively</b>								
Initial price	2	1 / 2	2	2	1	1 / 2	1 / 2	1 / 2
Risk management	1	1	3	1 / 2	0 / 1	2	2	2 / 3
<b>Principle 6: Develop continuous improvement</b>								
Continuous improvement	0	1	3	1	0 / 1	1	1 / 2	3
<b>Principle 7: Mobilise and develop people</b>								
Development of people	0	2	2 / 3	1 / 2	1 / 2	3	3	3

## 4.2 A relative comparison of main contractors and suppliers

Comparing the two types of companies, it is easily noticed that Principle 4 and 7 are better exercised by suppliers. Principle 4 ‘Integrate project activities’ encompasses the involvement of partners and the integration of processes and activities, which due to a supplier’s greater specialisation is found to be more straightforward to manage. Principle 7 ‘Mobilise and develop people’ could be explained with similar reasoning as individuals are of greater importance in the delivery of actual value in relation to their particular speciality. In addition, although the variation in scores is not high, it should be noted that main contractors, largely considered by Holti et al. (2000) as the leaders of SCM implementation, do not score particularly high in order to take up that role.



### 4.3 A case study: Another comparison

The fourteen companies involved in the case study are linked through long-term agreements for the construction of dwellings in three different regions of the Netherlands. For most of the key supply categories the main contractor has selected one supplier, except for categories related to the finishing stage, where the main contractor prefers to work with one supplier per region. All selected partners (see Table 2) are evaluated to indicate their SC Maturity at the beginning of their collaboration, following the method used in the first study. This Section focuses on the findings in relation to three themes – insight in cost components, margins and waste levels – and a total of eighteen sub-themes, characterising Principle 1 (insight in cost components is added to the original themes in this second part of the research). Table 4 gives an overview of the scores achieved, in which the sub-themes are averaged and reduced to six.

With regards to insight in cost components directors (showed as bold) on average show a higher score, sometimes even reaching 3.4 or 3.8, compared to other functions within the companies. In all cases, knowledge of general costs is limited to the own organisation and therefore, in most cases does not exceed a score of 2, and risks are known differentiating from score 0.7 to 3. Production companies (Supplier T3, T4, T6, T7, T9 and T13) seem to show unusually high scores on some elements, most probably due to their early involvement and a strong dependency on a limited amount of other partners.

Table 4: Overview of the three themes (Principle 1) and SC Maturity ratings.

	Insight in cost components			Insight in margins	Insight in waste levels	
	Material/Labour	General costs	Risk	Margins	Hours	Duration
Contractor T	2.8	2.6	2	2	1.6	3
Supplier T1 *	<b>3.4</b> ; 1.6	<b>2</b> ; 0.6	1	<b>2</b> ; 2	<b>1.6</b> ; 2.3	2
Supplier T2	2.2	2	0.7	<b>1</b> ; -		1
Supplier T3	<b>2.2</b> ; 1.4	2	2	<b>2</b> ; 0	1	<b>1.6</b>
Supplier T4	2.4	1.6	1.5	2	1	1.5
Supplier T5	<b>2.6</b>	2	<b>2.5</b> ; 1	<b>2</b> ; 2	1.3	2
Supplier T6 *	2.8	<b>2</b>	1	<b>2</b> ; 2	0.3	2.6
Supplier T7 *	<b>3.8</b>	<b>1.6</b>	<b>1</b>	<b>2</b>		
Supplier T8	2	<b>2</b> ; 2.6	4	<b>2</b> ; 2	<b>3</b>	<b>2</b>
Supplier T9	1.4	<b>1.3</b>	2	<b>2</b> ; 0	<b>2</b>	3; 2.6
Supplier T10	1.8		<b>2.5</b>		<b>1.3</b>	2
Supplier T11	<b>2</b> ; 0.6	<b>2</b>	1.5	<b>2</b> ; 0	<b>1</b>	2
Supplier T12 *	1.5	1.6	3	1	2	3.8
Supplier T13	<b>3.2</b>		2.5	<b>2</b> ; 0	<b>2</b> ; 1	<b>2</b> ; 2

It could be concluded that all companies have an equal insight into margins, limited to their own level (score 1 or 2) and therefore, no insight into their direct partners' nor suppliers' margins. Insight in waste levels differs from score 0.3 to 3.8. The companies that score higher turn out to be familiar with the Lean philosophy (marked with \*) and its implementation within their processes. Even so, insight is limited to just parts of the process – their own process – rather than the total process. The main contractor, again, does not score particularly high regarding all three themes.

## 5. Conclusion

SCM can support the move away from traditional adversarial relationships prevalent in construction supply chains and provides an opportunity for the delivery of more value to clients. This value is derived through collaborative working, easier knowledge transfer and the creation of long-term effective working relationships. This study focuses on collaboration at the lower tiers of the construction supply chain, particularly the collaboration between main contractors and suppliers – this collaboration was described as challenging with characteristics that obstruct successful implementation of SCM – and it describes the potential of main contractors as focal companies or supply chain integrators.

With their central position in the management of supply chains, it is believed that main contractors have more influence on the organisation of the project, and on the performance and quality of the work of its suppliers. This research uses Holti et al.'s approach (2000), which involves single point responsibility to the client with a collaborative model of overall leadership in achieving value for money, to effectively integrate supply chains, and its seven principles to investigate the maturity of different supply chain actors. The developed SC Maturity levels proved to be valuable in reflecting the environment in which the participating companies attempted to deal with SCM, and to compare the internal organisation of the two different types of companies with regards to essential SCM elements. It has shown that firms are faced with many barriers in the process of SCM implementation. Organisations were found to be particularly struggling to compete through superior value, manage costs collaboratively, and develop continuous improvement within their supply chains. The findings also underline the low SC Maturity of main contractors. Further investigation, based on a case study involving an initiated supply chain, reveals the limited insight in margin levels, many unknown components in costs and differing knowledge of waste – most organisations, including main contractor organisations, only seem to focus on information within their own boundaries.

The findings of this study have a number of important implications for future practice. First, the study highlights the need for a greater degree of main contractor leadership – especially when main contractors would need to take the important role as supply chain integrators – and improved internal organisation of both types of firms in order to achieve greater collaboration at the lower tiers of the construction supply chain. In addition, this paper lays the basis for further development of the SC Maturity levels and the first steps towards changing it into a usable improvement framework that could be applied to main contractors' (and suppliers') SCM activities.

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# Design Management – Learning across trades

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## Abstract

The Architecture, Engineering and Construction industry (AEC) has a potential to increase its productivity and increase the value of its projects. There is a common apprehension that the overall performance of AEC industry has not evolved at the same pace as the performance of other comparable industries. The increasing complexity of AEC projects that follows the rising focus on energy efficiency and sustainability renders it even more important to reduce the deficiencies in building design. The AEC, shipbuilding, and offshore construction industry are all project-based industries, mainly consisting of designing and manufacturing unique products for different customers. These similarities make the comparison of these three trades interesting. In addition, the offshore construction industry and shipbuilding industry are typically both recognized to have a high level of complexity. As AEC-projects get more complex, this renders knowledge transfer between these industries pertinent. This paper reports on a pilot study, undertaken in order to identify main differences and possible similarities between the trades, specifically questions pertaining to the management of design. The methodological approach chosen consisted of a literature review, a document study, and interviews with key participants from an AEC contractor, a shipbuilder, and an offshore contractor. The interviews were carried out as group sessions with two or more participants at a total of 11 sessions. In this paper we highlight two key processes, planning and coordination, and furthermore, we present the learning potential between the different trades.

**Keywords:** Design Management, Planning, Coordination

# 1. Introduction

The AEC (Architecture, Engineering and Construction) industry has a potential to increase its productivity and to increase the value of its projects (Bråthen, 2015; El. Reifi & Emmitt, 2013; Mejlænder-Larsen, 2015). Different authors have criticized the AEC industry for its ability to evolve and increase its performance (El. Reifi & Emmitt, 2013; Hansen & Olsson, 2011; Pasquire et al., 2015; Rios et al., 2015). Industries such as the offshore construction (OC) and shipbuilding (SB) industries have evolved faster than the AEC industry (Grimsmo, 2008). As AEC projects increase in complexity, could the industry learn from other trades who are recognised as tackling such complexity? The OC and SB industry are typically both recognized as being characterised by a high level of complexity (Aslesen & Bertelsen, 2008; Lia et al., 2014). In addition, the AEC, SB, and OC industry are all project-based industries, mainly consisting of designing and manufacturing unique products for different customers. These similarities make the comparison of these three trades interesting.

This paper reports on a pilot study with three Norwegian companies from these industries. The main objective was to find the similarities and differences in order to identify potential improvements for design management in the AEC-industry, while the actual process of learning is beyond the scope of this paper. The research has revealed some specific areas – like planning, coordination and design management – where the potential for learning across the trades is especially high. At the same time it must be acknowledged that the contextual frameworks of the trades vary, making a direct replication challenging. The research was carried out according to the following three research questions:

- What characterize projects in the three different industries?
- What key process characteristics stand out as of particular importance?
- What learning potential lies in these key characteristics for the AEC-industry?

Typically, the AEC-industry is characterized by strong sequential mindset (Kestle & London, 2002). This influences both project and design management (Knotten et al., 2014). The potential value creation depends on reciprocal design processes, which are difficult to plan and manage (Hansen & Olsson, 2011). A potential value creation is well recognized in the theory, but only to a limited degree implemented in the industry. Our findings aim to analyze to what extent this gap can be addressed, using insights and practices from other industries

## 2. Theoretical Framework

The three different industries (AEC, SB and OC) can all be classified as engineering-to-order firms. This means that the firms in those industries know little to nothing about what specific to produce before the customer delivers a receipt i.e. all production is customer driven. Furthermore, engineering, design and production activities are all part of the customer order lead time (Bertrand & Muntslag, 1993). Although firms in the three industries described in this paper are all engineering-to-order firms, there are some areas those kind of firms usually differs (Bertrand & Muntslag, 1993): the complexity of the products, the degree of customer specificity of the product,



the lay-out and complexity of the production process, and the characteristics of the market and competitors

The AEC industry is a fragmented industry, relying on many different actors from the start to finish of the project (Kerosuo, 2015; Zidane et al., 2015). This can cause problems with communication and teamwork within the construction projects. As Dainty, Moore, et al. (2007) describe, large project based organizations can experience communicational challenges between the temporary project and the permanent functional organization. Further, given that a construction project are organized in several phases and consists of several different actors from different organizations, more opportunities for communicative problems can arise. This typically arises out of the fact that different organizations involved in the project have different tasks, cultures and objectives. The scope of work in the AEC industry also varies from i.e. refurbishment of a house to multi-billion-hospital project, differencing in both economical size and complexity. The scope also affects the organization of the projects in competence, size and culture (Dainty, Green, et al., 2007).

The OC industry is characterized by outsourcing services, relying on different vendors to do one or more of their activities. This is a strategy used by OC companies to cut costs and focus on their core competencies (Khan et al., 2003). E.g. a company producing housing rigs on an oil platform have their core competencies in producing those houses and might have less experience in IT services. A service necessary to administrate the production of those houses, but not a service that the company can compete with other pure IT company on. Therefore, outsourcing of this service might be a cost reduction for the company, as to the opposite of having an internal IT division. However, later years there has been little proof of cost savings with outsourcing (Olsen, 2006). Furthermore, there is evidence that the industry have started outsourcing high complexity engineering services in addition to services like IT-support (Olsen, 2006).

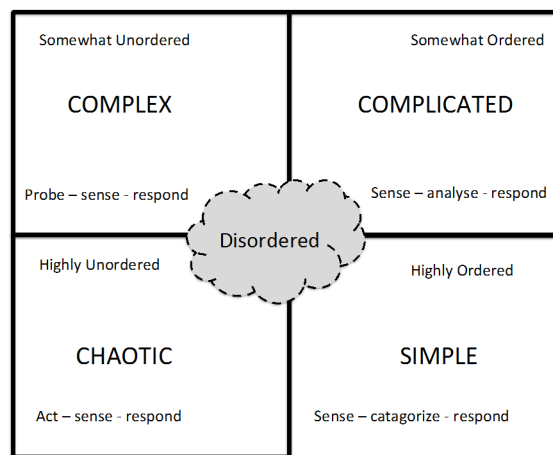
The SB industry is characterized as an industry with clusters of several different companies working together in alliances to form the whole supply chain (Wickham & Hall, 2006). The industry is competing in a global marked, which has changed the Norwegian industry over last two decades to work more multi-located and dispersed (Kjersem & Emblemståg, 2014). The increasing complexity of the vessels task leads to more complex products (Aslesen & Bertelsen, 2008). Kjersem and Emblemståg (2014) view the flexibility of the Norwegian industry as a competitive advantage, being able to produce complex vessels adapted to each client's needs. Dugnas and Oterhals (2008) list four key-production phases in SB, hull fabrication, primary outfitting, final outfitting and testing. The hull is typically produced in low-cost countries, whilst the outfitting is done at a Norwegian yard.

The characteristics of these three industries impose differences in the design process and management. Trying to achieve learning across the trades requires a deep understanding of these characteristics and their consequences.

Several theoreticians argue that there is a difference in managing a design project vs. a production project e.g. (Boyle, 2003; Jerrard & Hands, 2008). The design process is more challenging since

it is not a purely linear process (Boyle, 2003; Knotten et al., 2014). The importance of design in order to create a successful project are commonly highlighted (e.g. (El. Reifi & Emmitt, 2013)), and the importance of a design management to ensure the value of the project (Hansen & Olsson, 2011).

The design phase is regarded as one of the most challenging parts of a project, and the management of the early design phase in particular. There is the general nature of the process, which varies from a creative reciprocal process to a straight sequential production process (Knotten et al., 2015).



*Figure 1: The Cynefin framework adapted by Walker(2015)*

Projects can be looked upon as complex, yet the complexity can be defined in many different ways. A complex system has many typical characteristics such as it involves a large number of non-linear interacting elements, in which a small change can produce large major consequences (Snowden & Boone, 2007). Snowden and Boone (2007) use the Cynefin framework to describe the context of the situation. The framework describes five different domains, in order for a manager to make de appropriate choices. The domains are simple, complicated, complex, chaotic, and disordered. See Figure 1.

The Cynefin framework of management is also relevant for understanding complex AEC projects (Klakegg et al., 2010; Walker, 2015). This is especially true regarding design and design management, where the processes themselves are complexly interdependent (Knotten et al., 2014; Knotten et al., 2015)

Kalsaas et al. (2014) argues for Scrum as a tool to work with complex design problems, thus trying to make complex system simpler, short-sighted and to capture critical activities. Scrum is an iterative and incremental project management approach, that delivers result in increments called sprints (usually a 2 – 4 week iterations, however, it's up to the management team to evaluate the needed sprint intervals). A sprint starts out with a planning session and ends up in a review. The planning session is a box meeting where the scrum team is dedicated to develop detailed plans for the sprint. The review meeting is where the scrum team meets the stakeholders and

managers to assess and review the state of the business, market and technology. There is also a short daily sprint meeting where scrum team members address the questions: “what did I do yesterday?”, “what will I do today?” and “what impediments are in my way?” (E. Hossain et al., 2009; M. A. Hossain & Chua, 2009).

A major trend within the AEC-industry is to adapt VDC and Lean principles to the design management, but is also using elements from Scrum and Agile thinking. The OC and SB started with elements from Scrum and Agile thinking, but have also adapted Lean Principles.

A challenge of planning in design vs. standard management planning is that the design process consist of both sequential processes and reciprocal processes (Knotten et al., 2014). Typically the creative design process of problem solving as described by Lawson (1997), are viewed as reciprocal. The reciprocal interdependent process are thus difficult to plan since cutting them short they fail to discover the best solution and letting them run indefinite creates a progress problem for the whole project (Knotten et al., 2015). Olsson et al. (2015) suggests the use of agile methods in order to deal with reciprocal activities.

How to implement the new knowledge between the trades is not a part of the paper. It is noteworthy, however, to mention some of the research done in the AEC industry concerned with the question of barriers of learning. Skinnerland and Yndesdal (2014) points out problems with unlearning, organizational structures and norms as barriers of learning. Christensen and Christensen (2010) raise the question of the difficulties of learning because of syntax, semantics and motivation between the trades in AEC projects.

### **3. Methods**

This paper compares characteristics of the AEC-industry with those of the SB- and OC industries respectively, by studying internal documents and interviewing key stakeholders. Primarily, this case study was carried out according to the recommendations of Yin (2014). According to Yin (2014) “a case study is an empirical inquiry that a) investigates a contemporary phenomenon within its real-life context, especially when b) the boundaries between phenomenon and context are not clearly evident. (...) In other words, you would use the case study method because you deliberately wanted to cover contextual conditions”.

The bounding of the case is to understand how different trades execute design and design management. Each of the companies represent a large actor in their trade and have invested in measures for integrated methodology for design management, in order to be a lead actor in their trades. The research has been done by interviews and presentation of their way to conduct business. The sessions are semi-structured interviews letting the informants present and placing follow up questions. There are conducted 11 group interviews, which are transcribed. Along this there is done a literature review concerning design management & engineering management according to the recommendation of Bloomberg et al. (2011).

## 4. Findings

The study shows that the AEC industry is usually set up with consultants and contractors apart. Few, if not none contractors have their own design crew. The designers and engineers are there procured at each project. A typical constellation would be a sub-contractor responsible for the function of his deliverance, i.e. responsible for the design as well. This means that the project team is new and there actually is an opportunity to gain new experience for the team. This seems not to be exploited; instead, a post-project evaluation is planned in order to learn the key-takeaways of the project.

The architect and consultants are often hired directly by the client at an early stage of the project to make a brief. If the contract is a design-build, the architect and/or the consultant might be transferred to the contractor. This might lead to a conflict of interest between the architect pursuing the goal of a perfect building and the contractors view to only build what is in the brief.

The ship builder (SB) differs in several major aspects. Firstly, is the project a customized or a standardized ship project? The standardized ship is a known design with a few options that can be chosen. Changes from that or completely new designs are viewed upon as a customized ship.

Secondly, if the project is to be built at the builders own yard or at a remote yard in e.g. Asia. Will the whole ship be built off-site or parts for an onsite assembly? This is solved in different ways depending on the complexity of the ship and the timeframe.

Very often, the designers take out a previous design as a starting point when they try to fulfill the client's requirements of speed, handling and function. The function and the planned whereabouts of the ship is important since this affects critical design solutions as e.g. the power plant, hydro dynamics and the design. A ship operating in arctic weather needs a different layout in order to minimize the icing of the ship. The feasibility of the projects starts with the alignment of hydrodynamic capabilities, engine possibilities and propulsion, deeming these as the most important problems to solve. When this is solved, the design of the hull can finish and production starts. The engineering process is often parallel between design and production, narrowing the options of change as the parts are finished produced. The SB has an own department of engineers to develop the projects. When the project is realized, an engineering department takes over, very often with a complete new team. The transition is often made through a "kick-off" meeting and a common "audit" of the project. The engineering team consists of in-house personal, though they can be multi-located. The multi-located engineers have different cultures and this can be a challenge for the manager of the engineering.

The planning of engineering is based on deliveries to the production, as in drawings. This is monitored by a computerized planning system linking working hours to drawings. This does not monitor the value creating processes.

The offshore construction company (OC) delivers a part of a larger production system, and therefore has a lot of predefined interfaces both in space, weight, and technical requirements. All

these are predefined before commencing the work. Even though the company deals with EPC (Engineering-Procurement-Construction) contracts, the company can be viewed as a supplier. The clients of the company are mainly large OC companies with long experience that knows what they need and what they want.

Like the SB, the OC has its own design team. However, the OC has a design team that consists of the same members through the whole design process. When the workload is high, they hire in extra crewmembers to the projects to help offload some of the work from the key members of the design team. Keeping the same design team thru the whole process ensures that the knowledge gathered from early design phase is brought thru the whole design process. To ensure that knowledge from construction is brought into design, key members from construction are brought into early design. However, if the construction members have a lot to do at the production site, they usually do not have time to participate in the design meetings.

Another clear advantage with having all the design trades in-house is the teamwork on each project. When the members know each other, they do not need a lot of team building exercise to get to know each other before the project starts. Further, they all have the same organizational culture. This ensures that they all work to achieve the same goal of the project and the company. The trust between the different design team members is already build before the project starts.

The design process at the OC follows a stage-gate model with clear deliveries at each stage. At the start of the project, key members of the design team collaborate and agree on a matureness level needed to proceed to next stage. The maturity level of each stage can typically be the Level of Detail (LoD) on a model and the placement of those elements in the model. The designers use BIM as a main tool for design. When an area in the model reach the correct maturity level for the given phase that area is frozen in the model. Not allowing the designer to do further changes within that area on the model. E.g., pipe-support needs the numbers and sizes of the pipes to be modeled correctly, when they are finished modeling the pipe support they freeze it and gives it a predefined color, which means that the option to add more pipes or alter the size is of the pipes is not gone.

When the BIM is considered finished and the client approves of the design, detail drawings are drawn in 2D. Designers in low cost countries sometimes handle the detail drawing process, to cut cost and to offload work from the company designer. Although, the design is complete and no new elements are brought in when this process starts, it requires a strict quality control system. Furthermore, it is very important that the decision to move to detail drawing phase is acknowledge by the client and that client understand that a change order after the detail drawing starts will be costly. Figure 2 shows a comparison of the design process in the different trades.

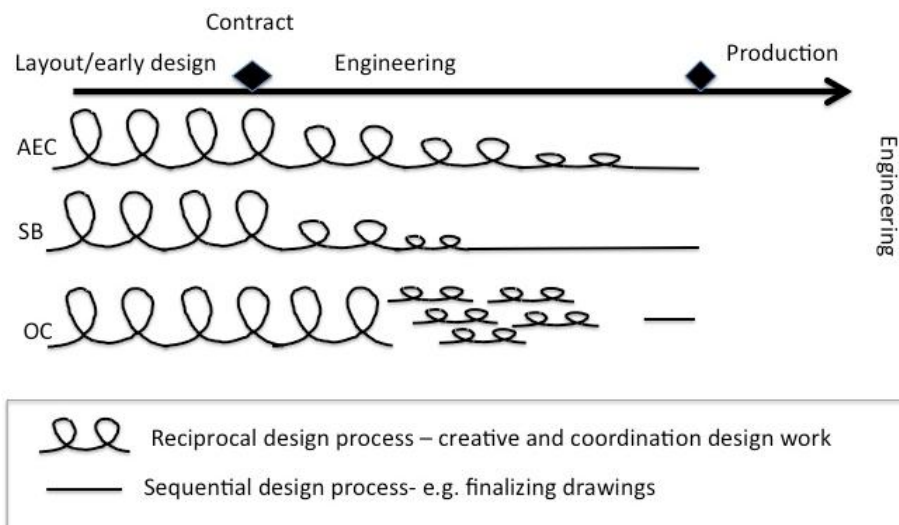


Figure 2: Design process in different trades

Before fabrication, the fabrication-engineering department takes the detailed 2D drawings and makes fabrication drawings. Those drawings are very detailed and focused on the information needed for fabrication. E.g. details of steel bolts and bends needed for the fabrication. The members of the engineering-fabrication department all have long experience from working in fabrication. They understand what is needed and how detailed the drawings and description needs to be.

The complexity of the products, processes and context varies from the different trades. There is a difference between an office building, Platform Supply Vessel (PSV) or an oil derrick. The complexity can differ in technical challenges, interconnections, time frame and other dependencies. Yet some of the tasks are similar. Design or engineering is about transforming the needs of the client and user to a finished product. In table 1 we present some of the key characteristics of the trades.

Table 1: Key characteristics of the trades

	AEC	OFFSHORE	SHIP-BUILDING
Project-based production	Yes	Yes	Yes
Unique products	Yes	Yes	Yes
Use of Sub contractors	Yes	Yes	Yes
Own design team	No	Mostly	Mostly
Common production site	No	Yes	Yes
Prefabrication	Some	Yes	Yes
Contracts	DB	EPC	EPC
Competition	Local	Global	Global
Professional Clients	Mostly	Yes	Yes

## 5. Discussion

The characteristics of the AEC-, Shipbuilding (SB) - and Offshore Construction (OC) industries are discussed previously in the paper and summarized in Table 1.

Through the results from our studies we ended up with two important key processes where we think the potential of improving is important, notably planning and coordination.

Planning is an important part of design management. The planning processes between the three industries are partly similar. Production methods usually set the framework for the design plan. This is usually carried out by an assumption of what production material (e.g. drawings) needs to be finished at what time in order to have an efficient production. However, using drawing as a measure of design creates some challenges. The drawings are the deliveries from the design process to the production process and just measuring according to that, do not say anything about the quality and value of the product, i.e. the design. Furthermore, the design process is inherently a creative reciprocal process (Knotten et al., 2015), creating challenges in coordination and planning of the design process (see Figure 2). Spending more time designing can increase the value of the product, by a better design. However, the project is time restricted and knowing when the correct point to stop the creative process is difficult. A focus on more than just deliveries of drawings is needed. The SB tried to estimate the workload by experience of making drawings. More drawings make more workload. For the AEC contractor, drawings were more a tool to check of finished work and measuring progress. The OC had a different approach and measuring maturity for the designed products. This meant that there was a focus on getting the product right in the BIM, rather than to just measure produced paper.

The use of coordination tools such as BIM differenced also in the studied cases. In the AEC industry, the use is still on a modest level of detail. The models main purpose is for coordination and visualization of solutions, and as the foundation of drawings. The SB used BIM in the detailed engineering, as at coordination tool. The OC had set a purpose for the use of BIM, and this was linked to stages of the design phase and to the development of the design. At certain level of the design-phase, the model would be at an agreed level of detailing (LoD). When this was coordinated, through model checks, the design was frozen and the elements marked in a particular color, letting everyone understand that these components were at certain stages. Components also evolved during the design phase, from placeholders to detailed models of the real thing.

What learning potential lies in the key characteristics for the different trades? The way OC uses BIM as coordination and planning tool is one of the key characteristics the other trades could learn from.

In planning for the design phase there is a focus on reaching the product, which are drawings for production. By using the amount of drawings, you get a timeframe for the design process. However, the OC focused more on the task and the objects in the model, and using that as milestones in planning the design. This is a planning method that both the AEC and SB can adapt and use. This would be more of a stage gate method(Klakegg et al., 2010), where maturity,

objects, decisions, together with production and procurement would dictate the plan. This together with collaborative planning (Bølviken et al., 2010; Fundli & Drevland, 2014) would help to create better plans.

Using BIM in larger extent to coordinate the work would benefit the AEC. Still there is a hang to use drawings for coordination, but by using the model as the OC uses it would reduce the amount of drawings. This together with the plan would help to get a more efficient design phase. The OC uses sprints to address complex engineering issues; the AEC uses a variation of ICE. The use of sprints, by clearly defining objectives, stakeholders and a timeframe is an efficient way to deal with complex problems (Lia et al., 2014).

## **6. Conclusions**

A comparison of the AEC, Shipbuilding (SB) and Offshore construction (OC) industry shows that there are a lot of similarities, but also some differences, as presented in table 1. The main differences are that the SB and OC, have in-house design teams, fixed production sites and are competing on a global market. There are also several contextual differences regarding framework, culture etc. The similarities are mainly in the fact that they are project-based producers of unique products, and they have similar contracts forms. This makes the industries useful to learn across the trades.

In this paper, we highlighted two key processes, the planning and coordination of the design phase. These are equally important to all of the trades. The approach to plan and coordinate the design phase is different from each trade, but they are struggling with some of the same issues.

This pilot study shows that the AEC has learning potential by implementing planning and coordination methods used by the OC. The OC have implemented a new way of planning and executing the engineering, thus exploiting more of the benefits of BIM. By producing production drawings at the last responsible moment, they let the coordination processes last longer, leaving time for the design to evolve and mature. See figure 2. The OC has as the other trades a reciprocal design process before contract. After contract all designs processes are somewhat reciprocal, but the OC is divided in smaller concrete task. By using agile approaches such as sprints, OC can work through design challenges efficiently. After the reciprocal coordination work, the finalizing of the drawings is viewed as a sequential process.

In this paper we have compared the industries and identified the learning potential across trades. How the AEC industry should implement the methods of the OC industry is not discussed here. Research carried out on learning within the AEC industry identifies, however, several barriers to learning. It would be safe to assume that these same barriers also would apply for learning across the trades.

As this is just a pilot study the next step is to try out the suggested improvements in AEC projects, and report of the findings there.





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# Role of Power and Sense Making in the Briefing of a Small Renovation Project

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## Abstract

This action based qualitative case study research studies the role of power and sense-making in the briefing process in three small university renovation projects. It is essential for the heads to understand the role of power and sense-making in projects in order to pay attention to a sound decision making process. However, every project faces situations where the powerful heads are forced to decide how to continue when the sense-making process is too lengthy and the stakeholders are not able to tell what they want with the limited resources. This paper answer the research questions: how the power affects the decision making, and how sense-making can be organised in order to reach better decisions.

**Keywords:** Renovation project, briefing, decision making, sense making, power

# **1. Introduction**

At early stage of the project the broad scope and purpose of the project and its key parameters including overall budget and program need to be agreed. This process is called briefing, also known as architectural programming in the USA and Asia. During briefing a client's requirement is clarified and the design team is informed of needs, aspirations and desires, formally or informally (CIB, 1997). The transfer of decisions and all the information enables achieving a better understanding of the requirements and preferences at the project inception stage (Jenkins et al., 2012).

There are following challenges linked to briefing: lack of identification of client needs; inadequate involvement of relevant parties of the project; inadequate communication between those involved in briefing; insufficient time allocated for briefing; briefing information still given during late design and construction stages; and contractor having no real understanding of client objectives (Barret and Stanley 1999, Kamara and Anumba 2001; Yu et al 2005) . This paper focuses on the level of identification of the needs, aspirations and desires during the decision making process. The decisions are made by those who have power to make decisions and due lack of time with bounded rationality of the above mentioned needs, aspirations and desires of the stakeholders. The decision makers try to make sense of the situation and make decisions.

The research is qualitative aiming at describing the sense making challenge and role of power in strategic briefing. The case study analyses three small renovation project. This paper answer the research questions: how the power affects the decision making, and how sense-making can be organised in order to reach better decisions. .

The paper introduces in the chapter two the briefing process and how the decisions are made during briefing in other words how the stakeholders make sense and use their power. The chapter three introduces and analyses the case study. The chapter 4 discusses the finding and chapter 5 makes the conclusion.

## **2. Decision Making During Briefing**

The large construction projects planning is shown to be a time-consuming process, in which design disciplines carry out their design and analyses separately, and the number of possible iterations is low (Flager et al., 2009, Eastman et al. 2011).To enable creating the alternative design solutions, a decision-making process is needed to specify where project goals and functional needs are mapped (Schade et al., 2011). Iteration is natural to design and should be allowed between the client and practitioners in the construction process (Thomson, 2011, Sidwell,1990). The iteration process is believed to improve the quality of the end result.

## **2.1 Briefing process challenges**

Successful briefing identifies, understands, defines, and communicates effectively the needs and requirements of the client and stakeholders to the project team. There are number of success factors that help to define a brief (Yu et al. 2006). In this paper we are interested in the decision making. The success factors for decision making during briefing are proper priority setting and good record of decisions made. The successful decision making is also linked to avoiding conflicts that means consensus building prior to decisions. (Yu et al. 2005).

According to the survey made by Yu (et al. 2006) the most important critical success factors for briefing in descending order of importance are: open and effective communication with stakeholders; clear and precise briefing documents; clear intention and objectives of client; clear project goal and objectives; thorough understanding of client requirements; experience of brief writer; team commitment; identification of clients requirements; agreement of brief by all relevant partners; sufficient consultation from stakeholders; holding workshops with stakeholders; control of the briefing process; realistic budget and programming; consensus building ;and honesty of the team members.

## **2.2 Power and Sense Making**

In order to make good decisions the decision makers need to know what they know and what they don't know. The understanding of not knowing something leads to a sense making process either in shared mode or alone. Fast (et al. 2011) argue that power will, via an elevated subjective sense of power, lead to an overestimation of one's understanding in decision making.

Power is unequal control over valued outcomes (e.g., Emerson, 1962, Keltner, Gruenfeld, & Anderson, 2003, Fast et al. 2011). There is also evidence that experiencing an elevated sense of power – defined as the subjective sense that one is powerful and influential, regardless of whether this is actually the case (Anderson et al. 2012) – coincides with confidence-inducing states, such as optimism, risk-taking and exaggerated perceptions of control over outcomes (Fast et al., 2009).

Project partisipants need to acquire knowledge about the implementation of their tasks and project situation as well as opinions of different stakeholder groups. This learning process can be called sense-making in other words making sense of how the opinions of others, situations, problems and proposed solutions effect on how the project is implemented. The understanding vary between individuals, which means that the organizational learning (i.e., project teams' and project-based companies' learning) needs at least partially made possible through sense-making together in order to make it possible for individuals to understand what is done. With the help of sharing, the organizational learning transcends the individual level of learning (Koskinen & Pihlanto, 2008). According to Koskinen (2014) sense-making and negotiation of meaning are ongoing processes in project-based companies. Their roles are particularly strong within the projects in which the organizational learning takes place through problem-solving activities (Cyert & March, 1992; Levitt & March, 1988).

Smith (2012) found out that the project sense-making is social and partisan; enactive in other words created with artefacts that are tangible; it is dynamic, changing over time; the sense is driven by individuals. So sense is

- 1) based on single group power – the group of people are able to decide what is right and what is wrong
- 2) based on two party deal. The project scope is negotiated between a client sponsor and a supplier organisation from whom the delivery of the project is commissioned.
- 3) based on multiparty alliance – there might be different parties with whom the project owner negotiates (Smith 2012)

### **3. Case studies**

There are three case studies that illustrate the sense making process and the role of power in them.

#### **3.1 Case 1: Small renovation of a kitchen and open office**

The case is a small renovation project (budget around 30 000 Euros) of a university facility. The project was important for the end-users of the facilities since they needed updated facilities to improve the collaboration between the doctoral students. The head of the department initiated the project proposal. The stakeholders during the briefing process were facility users (professors, lecturers, researchers, doctoral students), designer, and facility management service. Decision during the briefing was to implement the change by using a small renovation by using only new furnishing in order to fit more doctoral students into the facilities the staff rooms were not changed. The coffee room got new door and lightning was fixed. The facilities were actually owned by another company that was also linked to the project. So even such a small project involved the end users, owner (client organisation), the facility managers (from the university and from the owner), and the acceptance from university that had to prioritise the funding for new furnishing and possible rent rise due to the renovation.

Description of the sense making in the briefing process:

- The initiator (head of the department) empowered the stakeholders the doctoral students and professors and others after having a permit from the facility management to start the process. The head talked with the professors separately about their viewpoint.
- The sense-making process was an ad-hoc process where everybody could tell about their wishes and complaints about the old facility spaces.
- Designer came to discuss with the head of department and made measurements.
- A voting of the colouring was arranged.

Role of power

- The facility manager could use power when he told that you can have the project if you are fast enough this year and make fast the proposal for his heads
- The head of the department used power when she discussed with the designer and selected the viewpoints to him without any proper drawings or notes.

The fast project

*Table 1: Case study findings of the department spaces*

<b><i>Fact</i></b>	<b><i>In the case study</i></b>	<b><i>Reason</i></b>
Project overall objectives were not clear	The end users did not know what kind of issues were possible due to lack of understanding budget possibilities	The facility manager was not tightly involved in the process.  The brief was not expressed in a written format.
Process – hurry	Superiors had more <b>power</b> than they actually wanted to use	There was no timetable or planned the process – everybody worked ad hoc
Unstructured Briefing Process	Short-sighted view of the needs  The process was not planned there was no information what was going on.	The long term plans were not discussed  Sense making process was not open
Conflict management	The team did not agree on the colour of the walls the green colour irritates still some people	The team did not pursue to find consensus.
All stakeholders did not participate briefing	The end-users did not know the boundaries like budget	The facility managers did not give budgetary boundaries or long term possibilities
Long term view	There was a need to modify the facilities after less than two years after the renovation	The long term view was lacking and soon
Sense Making and Power	Sense was based on two party deal (the department and facility management)	The decision making was done in collaboration with the facility manager and the department

### **3.2 Case 2: Small renovation of a lobby and restaurant**

The case is a small renovation project (budget around 200 000 Euros) of a university facility. The project was important for the university owner since they wanted to test new type of public spaces at universities. The end-users of the space found the goals also very important.. The researchers initiated the project proposal. The restaurant was found to be full all the time but many users of the restaurant complained that during rush hour the spaces were noisy and functionally also poor. The open space was empty almost all the time.



Description of the sense making in the briefing process:

- The initiator (researchers) empowered the stakeholders (the whole university students and all the staff) to answer the questionnaire where their wishes of the spaces were asked. More than 100 responses were got.
- The designer group made proposals based on the survey
- A voting of the best design was made together with researchers, students, facility owner and university facility manager.
- The university heads had started meanwhile projects that were considered more important than the public space project.

Role of power

- Empowering the university staff and students in describing their wishes for the public space done too fast without negotiating with the university heads.
- There were other projects that were seen more important for the university and the project was postponed for future.

The postponed project

*Table 2: Case study findings of the public space project*

<i><b>Fact</b></i>	<i><b>In the case study</b></i>	<i><b>Reason</b></i>
Project overall objectives were not clear	The end users did not know what kind of issues were possible due to lack of understanding budget possibilities	The facility manager was not tightly involved in the process. The brief was not expressed in a written format.
Process – hurry	The researchers did not wait until an official decision was made	No agreements were made and the research group processed in good will
Unstructured Briefing Process	There was no officially stated requirements. For how to start a briefing process	The long term plans were not discussed Sense making process was not open
Conflict management	The stakeholders never met	The consensus was never discussed
All stakeholders did not participate briefing	The end-users did not know the boundaries like budget	The facility managers did not give budgetary boundaries or long term possibilities
Long term view	The university facility managers selected the projects without discussing about them openly. No strategies were presented	The long term view was lacking
Sense Making and Power	Single stakeholder group made the cancelation decision	Though the stakeholders were empowered the university made the postponing decision alone.

### 3.3 Case 3: Renovation of a University Building

The case is a renovation project (budget around 300 000 Euros) of a university facility. The project was important for the university since the facility did not fulfil the current needs when the public restaurant moved away. The university owner initiated the project proposal.

Description of the sense making in the briefing process:

- The initiator (owner of the facility) empowered the stakeholders (the university staff representatives and some randomly selected students, facility owner and the professional construction experts like architect) to participate in a collaborative design stage where first the goal was set and then the concepts were generated and finally an illustrative mock up and models were presented for everybody who was interested.
- The professional designer made proposal based on the collaborative design stage
- The owners and construction professionals evaluated the costs and made a priority check for the project
- The real design started after the commitment from the university was got.

Role of power

- Empowering the university staff and students in describing their wishes for the spaces was done openly and also the professionals were invited to participate in the decision making.
- The university was able to see how important the project was for all the stakeholders and made the positive decision.
- The professionals analysed the concepts and models when finalising the design. The stakeholders were deeply involved.

*Table 2: Case study findings of the public space project*

<i><b>Fact</b></i>	<i><b>In the case study</b></i>	<i><b>Reason</b></i>
Project overall objectives were not clear	The end users did not know what kind of issues were possible due to lack of understanding budget possibilities	The budget was not set before the process. The brief was carefully described
Process – hurry	The process was short but well structured	The process followed a four day long Charrette like model
Unstructured Briefing Process	Look above	The process followed a four day long Charrette like model
Conflict management	The conflicts were solved	The consensus pursued via discussion
All stakeholders did not participate briefing	All the participating stakeholders got a deep view of the needs	The process was open. But everybody did not participate.

Long term view	The vision was clear for everybody	The vision was first created in the process
Sense Making and Power	Sense was based on multiparty alliance	The collaborative decision making was aim of the structured process.

## 4. Discussion

The research questions were

1. How the power affects the decision making?
  - Empowering the stakeholders requires orderly process. In case one the stakeholders were empowered but the process was not orderly and the stakeholders were only partly empowered
  - There are three different types of sense modes related to power and all of them were used during the case renovation projects.
2. How the sense-making can be given to stakeholders in order to empower them in the decision making process and finally get better decisions.
  - Orderly process where all the stakeholders are involved right from the beginning till the execution ensured the outcomes to be realised.

The hurry situations create easily situations where the decision makers use power and in addition the powerful situation can give overconfidence of the ability to tell what is actually needed (compare Fast et al 2011). On the other hand if the decision was not made there would not have been any modernisation (case 1).

The detailed brief documentation help the decision maker to remember what has been discussed (success factor of the brief documentation was not realised in case 1). Even in a small project the briefing process and specified brief is important (case 3). Lack of briefing document can be seen as reason for sense of power and overconfidence of the knowledge of the head understanding of the needs (case 1).

The need to hurry can give a possibility to have fast decisions but the disadvantage can be the wish to jump to solutions without thinking the long term plans (case 1 and case 2).

The findings of the case studies suggest that successful project should contain following stages:

1. The vision of the facilities,
2. Specifying the functions e.g. how many persons use at the same time the space

3. What kind of requirements the functions have for the space
4. Checking what is possible to be realised with the given budget
5. Prioritising the needs: a long term plan.

The case studies used all possible sense modes:

- 1) based on single group power – in case 2 the university prioritised the projects and postponed the proposed project without properly negotiating with the other stakeholders.
- 2) based on two party deal – during case 1 the project scope was negotiated between department and facility management
- 3) based on multiparty alliance – during case 3 the process involved different stakeholder groups in extensive four day workshop.

This paper analysed briefing processes of three small renovation projects and found that an orderly process can help in finding the plans that are accepted. In addition, the written brief was not important for the powerful decision maker since it looked like the decision makers could use their own explanation for their decision. The hurry situation and lack of written brief resulted a situation where the decision makers used a lot power (case 1).

The decision makers were overconfident of understanding the needs and thus they were not willing to openly discuss their decisions. The overconfidence resulted a space that looks good but is not used like in case 1.

## 5. Conclusions

This paper analysed briefing processes of three small renovation projects and studied how power affects the decision making and how sense-making can be organised in order to reach better decisions. Though the project studied only three cases the results suggest the need to have an orderly briefing process where all relevant stakeholders are involved.

The facility managers and construction specialists should be aware that the overconfidence that is got when own memory is trusted can lead to reach faulty directions and the just renovated facilities need renovation soon. In future it should be studied alternative sense making processes in different situations. It would be interesting to study whether the sense-making based on multiparty alliance is always important.

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# Key Enablers for Effective Management of BIM Implementation in Construction Firms

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## Abstract

In recent years, Building Information Modeling (BIM) has been characterized as a promising tool and approach to tackle the traditional problems inherent in architecture, engineering and construction (AEC) industry. Several AEC firms around the world have deployed BIM to execute their projects. However, the full utilization of BIM has not been achieved yet in mainstream AEC firms and on construction projects. The implementation of BIM is a significant concern for many construction firms as it requires changes in existing business processes to occur. Given the huge financial commitment and multitude of other challenges that a BIM project entails as well as the potential benefits arising from its successful implementation, it is significant to understand what is needed to ensure a successful BIM implementation. Based on a literature review and by using an approach grounded in business process change management theory, this paper aims to provide a better understanding about the enablers of BIM implementation. An enhanced understanding of the BIM enablers could help the organizations to avoid costly errors and mistakes in the process of planning for BIM adoption and implementation and to increase the potential benefits of BIM.

**Keywords:** Building Information Modelling (BIM), innovation implementation, Construction Management

# 1. Introduction

The Architecture, Engineering and Construction (AEC) industry has long been criticized for its low productivity in comparison to other industries, and the industry is facing challenges to fulfil clients' expectations and remain competitive. Traditionally, for any construction project a set of design and construction documents are generated largely through 2D CAD-based applications. The result is that the contractor ends up with a pile of 2D drawings that have to be measured and calculated manually in order to get the quantity take off for the project. The on-site planning, assembling of different building components, and coordination of large number of different trades/subcontractors are all difficult tasks to perform with 2D-based workflows. The nature of construction projects is such that they involve a large number of stakeholders and organizations, which require a high degree of collaboration and communication. A smooth flow of information, materials and other key resources is crucial to shorten the lead time and reduce uncertainty. It is the key facilitator for increased team collaboration and providing better value to the client (Titus and Bröchner 2005).

In recent years, Building Information Modelling (BIM) has been considered as an innovative technology and approach to overcome the traditional problems inherent in the AEC industry. BIM is changing the way construction projects are executed. It offers several new opportunities for the optimization of whole construction supply chain through the reduction in reworks, design and construction errors, and by providing reliable and reusable digital information about a building's whole life cycle.

The adoption and implementation of BIM, however also comes with many inherent risks and uncertainties. It is in fact a complex business process for many construction firms to manage it. Some may consider BIM as a mere technological innovation, but it should be re-classified as an organizational innovation (Succar and Kassem 2015). Organizational innovation can be considered as "a means of changing an organization, whether as a response to changes in its internal or external environment" (Damanpour 1991). In other words, organizational innovation refers to a new organizational method for undertaking business practices and/or external relations.

Implementation of BIM as an organizational innovation involves adjustments to the firm's values and culture for its introduction. It also involves significant change in organizational structure and infrastructure. Most importantly, BIM implementation involves a high degree of difficulties because it deals with significant change management and resistance of individuals to embrace the change. Due to these associated difficulties, the full benefits of BIM have not been achieved yet in the mainstream construction projects and firms (Gu and London 2010).

BIM implementation requires a well-planned and coordinated approach with due consideration different aspects of innovation management and implementation (Smith and Tardif 2009). Given the associated difficulties and a huge amount of investment required, a better understanding about the key enablers during the process of BIM implementation is vital. Since BIM implementation involves changing the business processes of construction companies, the authors believe that business process change theory may provide a better understanding about the key enablers in the



BIM implementation. In the following section, the theory of business process change will be further explained.

## **2. Theory of business process change management**

Business process change is defined as organizational initiative to design business processes to achieve significant improvement in performance through changes in the relationships between management, information technology, organizational structure, and people (Kettinger and Grover 1995). According to the theory developed by Kettinger and Grover (1995), “any significant business process change requires a strategic initiative where top managers act as leaders in defining and communicating a vision of change. The organizational environment with a ready culture, a willingness to share knowledge, balanced network relationships, and a capacity to learn, should facilitate the implementation of prescribed process management and change management practices”. In the following sections, the different elements of this theory will be discussed in detail.

### **2.1 Strategic initiatives**

Typically process change starts with strategic initiatives from the senior management team (Kotter 1995). These can happen as a result of reaction to a need or a proactive push to leverage potential opportunities (Earl 1994). Evidence also exists that strategic change, and arguably process change, is often incremental, informal, emergent, and is based on learning through small gains versus being revolutionary and radical. According to Shrivastava (1994), strategic initiatives can be forced on the organization through mandate or pushed through consensus within existing systems of the organization. Alternatively, champions of change could emerge to seek out creative ideas and make them tangible (Tushman and Nadler 1986). They engage in coalition building an information-intensive process of knowledge sharing and persuasion.

### **2.2 Cultural Readiness**

Organizational culture governs how people inside an organization learn, share information, and make decisions. The significance of organizational culture can be best explained in terms of cultural beliefs, values, and norms (Schein 1984). At the highest level, an organization’s beliefs symbolize the interactions between ideas and shape its interpretation of information and how it makes decisions. Value systems relate behaviours across units and levels of the organization, with values being shared by the organization as a whole or by distinct subunits. Values often exhibit a propensity to resist change because of their shared nature (Fitzgerald 1988). At the lowest level, norms are the unwritten and socially transmitted guides to behaviour. Norms that promote change include risk taking, openness, shared vision, respect and trust, high expectation for action, and a focus on quality (O'Reilly 1989). Norms that discourage change include risk avoidance, ambivalence, group think, and excessive competition (O'Reilly 1989). In short, cultural beliefs, values, and norms constitute an organization’s cultural potency to influence behaviour. Thus, leadership that can identify and influence cultural readiness for change can be a requisite to an

effective process initiative. Moreover, open communications and information sharing can promote a common culture and innovative behaviour among people inside an organization.

## **2.3 Learning Capacity**

The major goal of learning is to provide positive outcomes through effective adaptation to environmental changes and improved efficiency in the process of learning. Adaptation involves making appropriate responses to technological changes and learning from other organizations that have achieved the best practices in the industry (Freeman and Perez 2000). Increased efficiency can also be obtained through “learning by doing” (Arrow 1962) and accumulation of knowledge through cross-functional interfaces (Adler 1990). Such knowledge accumulation is also called declarative knowledge (i.e., a body of organized information) and can facilitate learning in a collective manner (Corsini et al. 1996). Higher level learning occurs when members reflect on past learning experiences to discover new strategies for learning. Learning can also be brought about by scanning external information. This can come from organizational employees who constantly review the environment for new developments and opportunities (technology gatekeepers), consultants who span the boundary between the environment and the organization (boundary spanners) and from the end users.

## **2.4 IT Leveragability and Knowledge-Sharing Capability**

IT is an organizational resource which enables the necessary means to accomplish knowledge processing and, hence, induce organizational change (Hammer and Champy 1993). Evidence suggests that IT led projects often fail to capture the business and human dimensions of processes (Markus and Keil 1994). A case is often made for the socio-technical design approach which suggests a mutual, bidirectional relationship between IT and the organization. Such an approach recommends synergy between the business, human and IT dimensions of an organization and could be promoted through cross-functional teams.

Communication technologies have also been proven to facilitate learning and knowledge development through a process of coordinated interaction among individuals. The ability to share knowledge enhances an organization’s tendency to change so that transparent data access empowers individuals and knowledge workers to reinforce one another’s expertise (Nonaka 1991). Thus, information and communication infrastructure and the extent of knowledge sharing can create an environment that facilitates successful business process change.

## **2.5 Network Relationships**

Research indicates that a successful change process requires leveraging of boundaries and relationships and balancing internal and external networks in terms of cooperation and competition (Nonaka 1991). Under most circumstances cooperative, interpersonal and group behaviour results in superior performance (Shaw 1958). However, it is possible that competitive controversy within generally competitive groups can result in greater openness, knowledge and understanding (Tjosvold and Deemer 1980). In terms of inter-organizational processes, research

indicates the benefits of connection with external partners. Organizations that can manage these aspects of competition and cooperation continuously can benefit from employee incentives and to instil change more effectively.

## **2.6 Change Management Practice**

Change management involves effectively balancing forces in favour of a change over forces of resistance (Strebel 1992). Organizations, groups, or individuals resist changes that they perceive as threatening them (Guha et al. 1997). It has been suggested that corporate transformation requires a general dissatisfaction with the status quo by employees who have to change (i.e. a readiness to change), a vision of the future, and a well-managed change process. The change management programme should address required cultural shifts in beliefs, values, and norms. Revolutionary and evolutionary change theorists propose contrasting tactics for accomplishing change which vary depending on the type of employee involvement, communication about the change, and leadership nature. Nevertheless, direct confrontation to forces of resistance will likely only increase resistance capacities. It is, therefore, suggested to use the theories of persuasion in changing attitudes to mitigate resistance and to understand “how” and “what” aspects and persuade the employees toward commitment and cultural assimilation (Melone 1995).

## **2.7 Process Management Practice**

Process management is defined as a set of concepts and practices aimed at better stewardship of business processes (Davenport 1995). It combines methodological approaches with human resource management to improve the outcome of business process change. Successful process management uses process measurement (use of process metrics, process information capture, improvement feedback loop, and process audit), tools and techniques as well as documentation. Evidence also supports the use of team-based structures both for the implementing the project and for designing the new process (Guha et al. 1997).

## **3. Key enablers for effective management of BIM implementation**

As discussed previously, BIM is an organizational innovation and a new approach in construction. The successful adoption and implementation of BIM requires a thorough analysis of different enablers. Based on the theories of business process change management, we have identified the key enablers associated with BIM implementation management which are summarized in Table 1.

*Table 1: A summary of the BIM implementation management enablers*

<i>Constructs</i>	<i>Enablers</i>	<i>Authors</i>
<b>Strategic initiatives</b>	Support from top management	(Arayici et al. 2011a)
	User's input	(Arayici et al. 2011b)
	Strategic vision	(Khosrowshahi and Arayici 2012)
	Strategic plan	(Arayici et al. 2011b)
	Stakeholder's analysis	(Arayici, Egbu and Coates 2012)
	Cost-benefit-risk analysis	(Mom and Hsieh 2012)
<b>Change management</b>	Rewards and recognition	(Peansupap and Walker 2005)
	User training and education	(Arayici et al. 2011b)
	Supportive supervisor	(Peansupap and Walker 2005)
	Management readiness for change	(Arayici et al. 2011a)
<b>Cultural readiness</b>	Existence of change agents	(Merschbrock and Munkvold 2014)
	Risk aversion	(Succar 2009)
	Early user involvement	(Miettinen and Paavola 2014)
	Open communication and information sharing	(Dossick and Neff 2009)
<b>Learning orientation</b>	Colleague's help	(Peansupap and Walker 2005)
	System expertise	(Eadie et al. 2013)
	Individual competency assessment	(Succar, Sher and Williams 2013)
	Learning-by-doing	(Arayici et al. 2011b)
	Community of practice	(Peansupap and Walker 2005)
	Learning from past experiences	(Arayici et al. 2011a)
<b>Knowledge capability</b>	Developing knowledge management system	(Arayici, Egbu and Coates 2012)
	Use of communication technologies	(Volk, Stengel and Schultmann 2014)
<b>Network relationships</b>	Inter-organizational linkage	(Homayouni, Neff and Dossick 2010)
	Cross-functional cooperation	(Cerovsek 2011)
<b>Process Management</b>	Setting benchmarking metrics	(Coates et al. 2010)
	Tracking benchmarks	(Giel and Issa 2012)
	BIM maturity assessment tools	(Succar, Sher and Williams 2012)

### Strategic initiative enablers

Top management support is required throughout the implementation process. Top management must be committed and willingness and actively are involved in the process and allocate valuable resources to the implementation effort. This involves providing the required human resource for the implementation and allocation of sufficient time to get the job done.

Managers should legitimize new goals and objectives. A shared vision of the organization and the role of the new system and structures should be communicated to the employees. New organizational structures, roles and responsibilities should be established and approved and conflicts should be mediated. Policies should be set by top management to establish new systems in the company. Top management of the organization must understand and analyse the sources of resistance and must employ the appropriate set of strategies to counter them.

Moreover, a clear business plan and vision to steer the direction of the projects is required for BIM implementation. A business plan that outlines proposed strategic and tangible benefits, resources, costs, risks, and timeline is essential. This will help keep focusing on business benefits. There should be a clear business model of how the organization should operate behind the implementation effort and a justification for the investment. Goals and benefits should be identified and tracked. The business plan would make work easier and impact on work.

### **Cultural readiness enablers**

Effective communication is critical to BIM implementation. Expectations vary at different levels, so they must be communicated. Management of communication, education and expectations is essential through the organization. User input should be managed in obtaining their requirements, comments, reactions and approval. Middle managers need to communicate importance of BIM implementation. Employees should be told in advance the scope, objectives, activities and updates, and admit change will occur.

A communication plan is important to involve the member with BIM initiative by showing them how it works, how it is related to their jobs and the benefits achieving from it. By doing so, resistant to change can be diminished. Moreover, it would be helpful to establish a communication program that can describe what should be communicated by whom and how often. It may help organizations to propagate their strategy. After implementation of BIM, it is best to publish the outcomes, but these should not be limited to success outcomes but also communication of drawbacks. It will help the future projects to avoid the same mistakes and from the past mistakes.

A champion is critical to drive consensus and to oversee the entire implementation process. They are the agents of change who should spread the BIM philosophy, benefits, as well as weaknesses throughout the organization. Someone should be placed in charge who has the power to set goals and legitimize change.

### **Knowledge and learning enablers**

Knowledge sharing and communication play a pivotal role in alleviating resistance to change and reducing risk and uncertainty. IT tools can facilitate the knowledge sharing process. Another key issue is creating a learning environment through a set of interrelated practices and beliefs within an organisation that enable employees to develop their own skills and learning. In such an environment, employees do not feel constrained by fear of failure and willingly participate in experimentation and risk taking (Klein and Knight 2005). Through “learning by doing”, members can learn how further efficiencies can be achieved through BIM implementation (Arayici et al. 2011b).

### **Network relationships enablers**

Although the training courses provide a wealth of knowledge in BIM initiative, it may not reinforce all the new knowledge and skills required to sustain BIM implementation successful. Throughout the implementation process, companies need to look at external organizations who are successful and leader in BIM implementation and learned best practices and methods from them. Moreover, the organization implementing BIM should work well with external vendors and consultants and/or internal divisions such as R&D to resolve users and software problems. Altogether, these aspects help them to transform from a trained organization to a learning organization.

### **Change management enablers**

Generally, when substantial change occurs inside an organization, the organizational members are afraid of the unknowns and might not realize the need for change. Some organizational cultures are fear based. Mistakes are not allowed, and employees are used to hiding errors. However, BIM as an innovation flourishes in an open and safe environment (Grilo and Jardim-Goncalves 2010) where mistakes are seen as improvement opportunities. Moreover, users must be trained, and concerns must be addressed through regular communication, working with change agents, leveraging corporate culture and identifying job aids for different users. As a part of the change management efforts, users should be involved in implementation processes, should be endowed by tangible or intangible rewards and should be provided with educational and training programs to improve their comfort zone. There should be extra training and on-the-job support for employees and managers during implementation. To meet users’ needs after initial implementation, a support which can be provided either by an external organization such as help desk or internal colleagues is critical.

### **Process management enablers**

Companies that adopt BIM must continuously improve their BIM performances and processes. Maturity assessment tools can be utilized to evaluate an enterprise’s performance in BIM utilisation during the initial stages. Furthermore, process measurement metrics and tools enable them to perform benchmarking. The application of most maturity evaluation tools is to assess the level of BIM performance within an organisation during the initial stages, and benchmarking tools and metrics allow a comparison between one enterprise’s BIM performance and that of their

industry peers. These enable them to benefit from the lessons learned and best practices from other firms and use them for further improvement and modifications in the organisation.

## **4. Conclusion**

The primary objective of this paper was to classify the BIM adoption and implementation enablers. The study identified that BIM is an organizational innovation and therefore needs organizational innovation principles to be taken into consideration. To this end, we believe the theory of business process change management may provide a better insight into the key enablers during the BIM implementation process. The results of this study should assist both practitioners and scholars and provide them with insights on how to better understand and prepare for BIM implementation. Specifically, this study tried to shed light on key facilitators of BIM implementation success that need to be focused for optimising the financial returns from BIM implementation. If any of these aspects are missing during the implementation of BIM, it would be the difference between a successful and unsuccessful implementation effort. However, the degree of influence of these factors may vary in different organizations. The key enablers identified in this study can serve as a checklist that covers the key success factors associated with BIM implementation for AEC firms.

During the BIM implementation process, an organization goes through a major transformation, and the management of this change must be carefully planned and meticulously implemented. We believe providing a conducive change environment supported by a set of change management as well as process management facilitators can help construction firms to better utilize from BIM workflows. Based on the theory of business process change management and through a review of literature, we identified a total of 27 BIM adoption and implementation enablers. The success of BIM implementation heavily hinges on the strong sustained commitment from the top management. An organizational culture where the employees share common values and goals and are receptive to change is most likely to succeed in BIM implementation. Moreover, user training, education and support should be available and highly encouraged. Change agents should also play a pivotal role in the implementation to facilitate change and to leverage the corporate culture. Maturity assessment tools can be utilized for process improvement.

In the next step of this research, we plan to assess the degree of significance of the key drivers identified in the literature and also compare a number of successful and unsuccessful BIM implementation. We are also interested in studying how the perceived importance of these drivers may differ across BIM implementation partners such as top executives, project team members, vendors and consultants. By having a better understanding of the key issues involved in BIM implementation, management and decision makers will be able to make critical decisions, better allocate resources and realize increased benefits from BIM implementation.

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# Assessing BIM performance through self-assessed benchmarking

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## Abstract

This paper describes research investigating what measures of performance of Building Information Modelling adoption can be standardised in creating an international benchmarking tool for self-assessment. By applying crowd-sourcing methodology to populating a prototype benchmarking tool, the research team aims to break down barriers of data and know-how ownership to encourage industry innovation to flow more freely. In particular, this research aims to answer the following questions: (i) Is self-assessed benchmarking a reasonable approach in assessing the performance of BIM at the project level?; (ii) Is crowd sourcing a valid method to populate the prototype? If so, how should the most appropriate metrics for benchmarking performance of BIM be selected?; (iii) What methods can be used to ensure the comparability, accuracy and consistency of the data input by users? The research described addresses these questions through an extensive literature review to build a foundation for future research combining the development and testing of a prototype tool with case studies and expert consultation in Australia and Sweden. This paper discusses key concepts used to develop the prototype and the requisite research being undertaken.

**Keywords:** BIM, performance, benchmarking, crowd-sourcing, self-assessment, selecting metrics, construction, capability, maturity

## 1. Introduction

Errors and omissions during design and construction phases in built environment projects are often the result of inefficient communication processes involving numerous stakeholders (Sebastian and van Berlo, 2010). These projects are characterised by being information intensive, putting pressure on enabling participants to have easy access to accurate and up-to-date information (Matthews et al., 2015). Hence, successful project delivery within the built environment industry requires accurate, effective and timely communication methods including

inter-organisational communication and information exchange (Becerik and Pollaris, 2006). This pushes organisations to move away from traditional inter-organisational communication and delivery methods towards implementing more effective contemporary digital methods, such as Building Information Modelling (BIM).

BIM can be viewed as a socio-technical system that is expected to contribute to a vast and rapid change in the built environment industry similar to that experienced by the automotive industry when Information and Communication Technologies (ICT) were introduced (Sanchez et al., 2016). BIM is considered to take the entire Architecture, Engineering, Construction and Owner-operated (AECO) sector to a new era in integrating data and communication and is in that regard perceived to be the future methodology of the industry (Tuohy and Murphy, 2015). The industry-wide and organisational changes, required to implement BIM more effectively and broadly, have already required significant capital and time investments from early adopters. It will also, most certainly, pose a challenge to the whole sector, equivalent to the move from pens to Computer-Aided Design (CAD); from main frames to hand-held devices. These investments need to be justified by measuring organisational value-added Key Performance Indicators (KPIs) monitored in terms of the effectiveness of the chosen investment strategy.

Other sectors that have undergone a digital revolution in previous years, such as the finance and banking sector, have been successful in documenting efficiency improvement through benchmarking indicators (Tuohy and Murphy, 2014), an example being cost per transaction. However, the built environment industry has a high level of inter-organisational relationships, which are different to many other industries and provide industry-specific challenges and opportunities. Even though a collective goal may be defined within the context of a single project, actors contributing to it may have particular interests that are not shared with other stakeholders as well as diverting perspectives and internal organisational goals. It follows that within a single project, different stakeholders may have different approaches to implementing BIM and different ways of thinking about and measuring performance. However, implementing BIM effectively, requires a collaborative and integrated approach in order to maximise efficiencies across stakeholders and life-cycle phases (Sanchez et al., 2016). As noted by Sebastian and Berlo (2010); “BIM comprises collaboration frameworks and technologies for integrating process- and object-oriented information throughout the life cycle of the building in a multi-dimensional model”. Benefits expected from implementing BIM include more effective, efficient, fast and error-free collaborative processes (Sebastian and van Berlo, 2010). Nevertheless, implementation and value monitoring strategies that have not been well defined and optimised through evidence-based processes can quickly lead to efficiency losses and cost overruns.

One of the main reasons for ineffective implementation and monitoring strategies to happen is the lack of standard frameworks to assess and benchmark performance within and across organisations (Sebastian and van Berlo, 2010). Although this area is progressing quickly, there is often a lack of appropriate guidelines that help organisations and project teams identify and prioritise performance requirements (Succar, 2010). At the same time, while there is a market-driven pressure for organisations to invest in implementing these kinds of technologies and processes, they may not be able to access sufficient information to justify such investment and

evaluate the effects of its implementation (Van Grembergen, 2002). Although organisational performance deriving from utilisation of BIM is important to justify investment, assessing the actual BIM performance at the project level is as important to understanding the effectiveness of the investment strategy. BIM performance is identified by Succar (2012) as being divided into BIM capability, the ability to generate deliverables and services, and BIM maturity, the extent, depth, quality, predictability and repeatability of the capabilities. Founded upon the above definition of BIM performance, this research proposes an internationally applicable open access system for project teams to develop internal BIM performance benchmarks while also providing the industry as a whole with cross-firm or industry benchmarks.

## **Research methodology**

The research presented in this paper has been developed as a descriptive review of literature based on academic publications and therefore based on secondary data. As performance assessment within the AECO industry in general and BIM specifically are relatively under-developed, parallels to different sectors and their frameworks have been analysed and described. This study has been conducted with the aim of contributing to the development of a tool for benchmarking BIM performance. Future research on the topic will possibly include development of new data and methodological considerations necessary for developing an actual tool. This research aims to answer the following questions: (i) Is self-assessed benchmarking a reasonable approach in assessing the performance of BIM at the project level; (ii) Is crowd sourcing a valid and relevant method to populate the prototype? If so, how should the most appropriate metrics for benchmarking performance of the use of socio-technical systems such as BIM be selected?; (iii) What methods can be used to ensure the comparability, accuracy and consistency of the data input by users? Future research will include testing the prototype tool through case studies and expert consultation in Australia and Sweden. This will provide insight into the potential application across international markets with different economic and implementation contexts.

## **2. Assessment of BIM performance**

According to Bassioni et al. (2005) the AECO industry has been noted by many for being complex, with high levels of conflict, underperforming, and characterised by low levels of productivity (Manderson et al., 2015). There is, seemingly, a need for developing ways of assessment that support improvement of BIM performance. Performance, a broad concept with, no widely accepted industry definition (Rankin et al., 2008), has different meanings between and even within sectoral contexts (Kouzmin et al., 1999). Performance in an organisational context has traditionally been measured through financial parameters such as return on investment (ROI) and is often criticised for providing a too narrow and one sided focus on organisational productivity and direct profit. In the AECO sector attempts at measuring performance in using BIM has mainly been focusing on measurable financial output in relation to time and quality at the organisational level (Bassioni et al., 2005). In doing so, it fails to take the total performance of BIM use into account with all aspects that contribute to a competitive advantage (Beatham et al., 2004), further it does not address the actual performance of using BIM. Liu et al. (2014) explain performance assessment as a process of quantifying and reporting the efficiency or

outcome of an action that is performed in line with an organisation's goals and objectives. The soft values or benefits generated through the use of BIM such as improved communications between project participants has to be included into an assessment of performance in order to provide more accurate results.

A case study on the Canadian AECO industry showed that this industry has historically lagged in labour productivity growth when compared to the rest of the Canadian economy (Rankin et al., 2008). This study further points out that this observation does not necessarily mean that the productivity is lower in the AECO industry. Instead it is suggested that measuring performance is more complex than it is in most other major industries. Additionally, AECO actors often have a more complex output and more versatile and dynamic way of conducting their business than in other industries. This again supports the thesis that traditional KPIs are not necessarily suitable to accurately represent overall performance as they might do in other sectors. (Rankin et al., 2008). When assessing the performance of BIM performance measured only through the above-mentioned financial indicators and other organisational value measures, it presents an incomplete picture. It requires abandoning some traditional methodologies and embracing more appropriate performance assessment to understand and develop business success (Liu et al., 2014). The use of traditional performance measurement indicators and frameworks can therefore be misleading and inaccurate when applied directly or partially to the assessment of BIM performance. A common understanding of how to define BIM performance assessment is necessary and has to be formalised.

In a project context BIM performance can be separated into capabilities and maturity. Assessment of BIM capability defines the minimum requirement for producing a task or delivering a service a project team possesses or is fulfilling. This can for example be the ability to produce a BIM model with a specific software. BIM maturity on the other hand distinguishes the project teams' quality, repeatability and degrees of excellence in which they perform the task or delivering service (Succar et al., 2012; Sebastian and van Berlo, 2010). This means that rather than determining what software is used, the BIM maturity determines how well it is used.

Identifying and collecting performance data is important in order to motivate and prove the efficiency that can be achieved by BIM implementation. However, many managers within the AECO industry may be reluctant to allow external parties to carry out this assessment. According to Costa et al. (2006), this unwillingness is a significant sign that AECO companies do not emphasise the importance of performance measures and benchmarks enough. This can be a reason why drive and development of BIM assessment is lacking. On the other hand, many organisations control and measure a wide range of other variables (Costa et al., 2006). Since performance data associated to BIM implementation processes and tools is infrequent, the most relevant metrics can be difficult to select when developing a framework for performance measurement. Having established what BIM performance is and why it is important, one has to identify what measures are already in use and how suitable they may be to assessing BIM performance in accordance with the performance definition.

## **2.1 Existing frameworks for BIM performance measuring and assessment**

There are a number of models and frameworks that have been developed to measure BIM performance by assessing the capabilities and maturity of individuals, teams or organisations (Månsson and Lindahl, 2016). These have been developed in an ad-hoc fashion and are, if not organisation-specific, likely influenced by the context in which they were developed (Bassioni et al., 2005). Frameworks that have been identified include the Interactive Capability Maturity Model (I-CMM, 2009); BIM Proficiency Matrix (Indiana University, 2009); BIM Maturity Levels (Bew and Richards, 2010); BIM QuickScan (Sebastian and van Berlo, 2010); BIM Maturity Matrix (Succar, 2010); Vico BIM Score (Vico, 2011); CPIx-BIM Assessment Form (CPI, 2011); bimSCORE (bimSCORE, 2013); BIM Planning Guide for Facility Owners (CIC, 2013); and BIM Competency Assessment Tool (Giel and Issa, 2015). These frameworks for measuring performance are still evolving and are applied differently across the market. The development of some of them has been driven by the industry while others have been driven by government or academic actors. These create different areas of focus regarding metrics and methods used.

Bassioni et al. (2005) stress the importance of not relying on a single framework and the metrics it includes. Given the diversity of organisations and projects within the AECO industry, it is unlikely that all relevant metrics are included in one framework or that all metrics included in a specific framework are relevant to all organisations and projects. On the other hand, utilising several frameworks may require a significant investment of resources and there is a risk that the frameworks may not be compatible. Månsson and Lindahl (2016) suggest that the frameworks presented by Succar and Bew/Richards are among the more ambitious frameworks for assessing BIM performance. However, Bew/Richards iBIM model is overly simplistic and by that unsuitable for comprehensively assessing BIM performance. The model developed by Succar grants a way to assess BIM Maturity, however it is perhaps over complicated and too resource demanding to apply.

The methods and availability of data necessary to measure BIM capability and maturity in more depth also require additional development. Further, most of the existing frameworks are not open access tools; they either need to be internally developed based on general guidelines or require investing in a consultant to carry out the assessment. Furthermore, they do not offer the possibility for industry-wide benchmarks and thus limits inter-organisational and industry-wide data sharing.

## **3. BIM benchmarking**

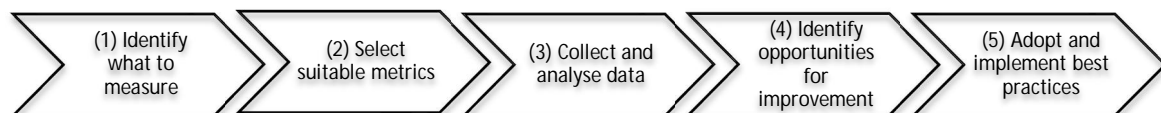
Among the main benefits of assessing performance through common criteria is the possibility to enable benchmarking. Within the context of this research and based on the general definition provided by Costa et al. (2006), BIM benchmarking is a systematic process of measuring and comparing organisational, project team and individual BIM performance with that of competitors or internally between projects; often with the objective to identify or determine best practices. In addition to assessing its own success internally, each organisation can use the lessons learned



from competitors in order to improve its BIM performance and through this avoid common mistakes as well as unnecessary re-work (Costa et al., 2006). In order to be able to benchmark externally throughout the industry, an internal assessment has to be performed. Internal BIM benchmarking can also be performed as AECO organisations tend to benefit from comparing the performance of their own projects from each other. In that sense it is difficult to separate internal from external benchmarking since one depends on the other.

If developed from within, initially as a way to assess BIM performance across projects, the size of the organisation can be critical in deciding the capability to assess. Kouzmin et al. (1999) state that only large companies can afford to develop their own method of benchmarking and that smaller organisations have to rely on frameworks already developed by and specifically for their larger competitors. This can affect the relevance of the metrics involved and potentially lead to misleading performance benchmarking results. However, internally developed frameworks for internal assessment later transformed into external ones, will most likely differ from those developed by others. From this perspective, it would appear that externally developed un-biased method for assessing BIM performance is required to make such a tool relevant and applied more broadly throughout the industry. According to Costa et al. (2006) there has been an increasing number of initiatives focused on developing ways of assessing performance of BIM in the AECO sector.

Rankin et al. (2008) defines the process of developing benchmarking as following a step-by-step plan (Fig 1): (1) identification on what to measure, (2) selection of suitable metrics, (3) gathering of data, (4) identification of what can be improved and (5) adoption of best practice (Rankin et al., 2008). The search for valid indicators and methods of data collection are critical elements of this process and can “make or break” the whole process if sub-optimised or poorly executed. While the characteristics of organisations within the AECO industry vary greatly based on the type of business they conduct, it is important to apply unified, reliable and valid metrics that allow a uniform and accurate measurement and comparison of their BIM performance. Assessment of BIM performance will also need to report on how a project team actually benefits through the utilisation of BIM. Figure 1 illustrates that it is a key activity to identify valid metrics when developing frameworks or methods of assessing or benchmarking performance. But what are the suitable, valid, metrics for a BIM performance benchmark? Can there be a way of overcoming the challenges brought by the fact that sets of metrics will have different level of relevance when comparing organisations?



*Figure 1: The process of benchmarking (Rankin et al., 2008)*

### **3.1 Self-assessing**

A common practice, in the process of assessing organisational performance, is that an external party, often a consultant, is both gathering and analysing the data. The main reason for this might be that organisations want a neutral party, or that it is required for accreditation, but also that the

process and most frameworks are too complex for the organisation itself to manage and the challenge of providing knowledge from within. A likely effect of this is that organisations distance themselves from the act of measuring, as responsibility will be more concentrated in the hands of external parties. Through this process the sometimes sensitive information used for internal KPIs is exposed to external parties who are likely to have competitors as clients which in turn may be viewed as a business threat (Rankin et al., 2008).

Self-assessment of performance can help make the assessment process faster and less costly, and grow internal 'ownership'. Pun et al. (1999) define organisational self-assessment as "a comprehensive and regular review of an organisation's activities and results against a systematic model of business excellence". Thus, it is proposed that applying a self-assessment methodology for performance benchmarks can save time and capital while at the same time build ownership. The assessment effort can also be ongoing, enabling continuous improvement processes in line with the dynamic and changing business climate in the AECO industry. Also, the continuous process of assessment and the continually-improving nature of the data may help increasing both the accuracy and the quality of the assessment. This is because parameters are up-to-date and updated as necessary and considered relevant by the users (Rankin et al., 2008).

### **3.2 Crowd sourcing**

A significant barrier, when developing a framework for organisational BIM performance assessment, is that the needs of different AECO actors will vary significantly between organisations and even between projects within a single organisation. It is unlikely that there is universal set of metrics for evaluating the BIM performance that is relevant to all actors in all scenarios. By allowing the user to select their own metrics from a default dataset, and add non-existing metrics where needed, the framework can grow organically, continually improving. This approach and methodology is in a way a type of crowd sourcing; here understood as a growing, efficient way of collecting data and by that building multi-variable datasets (Pierce and Fung, 2013; Amsterdamer and Milo, 2014). Therefore, a framework for self-assessed BIM performance constructed through crowd-sourced data gathering is proposed to be a valid way of developing a BIM performance benchmarking system suitable for the diverse and protective AECO industry.

### **3.3 Selecting valid metrics**

Developing a series of BIM performance metrics is a prerequisite and a paramount cornerstone in the process of creating a method for assessing BIM performance (Sebastian and van Berlo, 2010). Crowd sourcing a database of measures means it will grow organically to a certain extent. However, a generic framework with key metrics has to be provided initially to drive and support use. It is of great importance to build this first set in collaboration and consensus with industry actors from different disciplines within the AECO industry (Rankin et al., 2008). Metrics need to be (1) valid, (relevant, appropriate and justifiable) (2) quantifiable and (3) realistic (Fang et al., 2004). After the first dataset is created, early users can start selecting the most relevant metrics from the dataset that represents their view of key indicators of the BIM performance within their core business. In addition, they can request metrics that do not exist in the dataset to be included.

Through this process less used metrics can be removed, or at least valued lower and thus the framework will become more relevant.

To reduce the risk of having deceptive data affecting the tool through the self-assessed benchmarking affecting the dataset, the metrics have to be regulated to some extent and, as noted above, be anchored among the participating industry actors (Rankin et al., 2008). Some administrative control has therefore to be included in a potential tool. Fang and Wong (2015) developed a model for selecting metrics for assessing organisational resilience. Their model, here

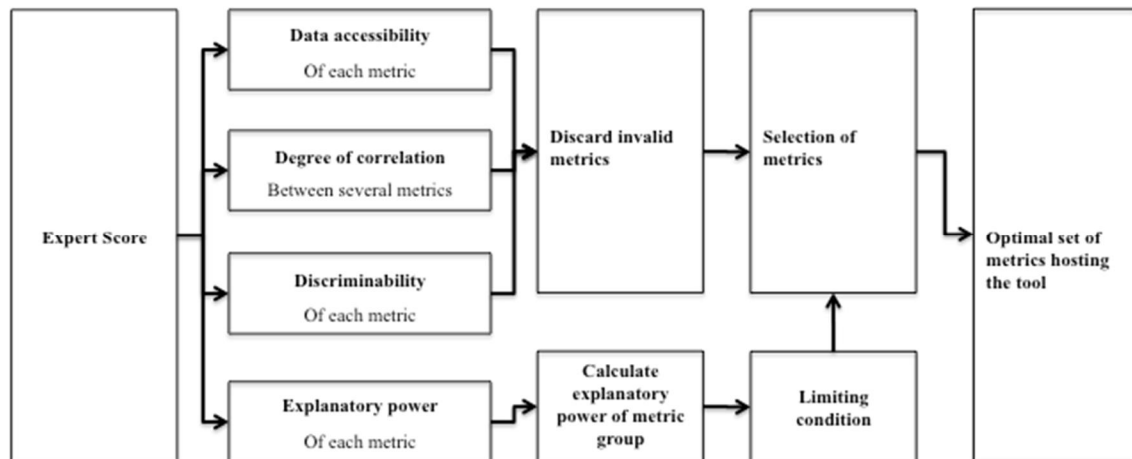


Figure 2: Process for selecting metrics for hosting the benchmarking tool- altered version (Fang and Wong, 2015)

provided with some minor alterations (Fig. 2), is also applicable for the process of selecting metrics for hosting a self-assessment BIM performance benchmarking tool. This implies that even if the user can add new metrics, there needs to be a managing entity that will validate it in accordance with the process provided in Figure 2. Further, the hierarchy of the importance or value of the metrics as well as whether they are fixed or changeable, has to be established.

## 4. Discussion

There are many metrics identified as appropriate and valid when scrutinising methods of measuring BIM performance. However, since the AECO industry consists of actors from many different fields, using BIM in sometimes different ways, it is impractical aiming to select an ultimate series of these metrics to serve as valid for all actors within the industry. Established frameworks and models for assessing BIM performance is either too simplistic (e.g. iBIM) or overly detailed (e.g. BIM Maturity Matrix) and therefore somewhat ill-suited for self-assessment. The self-assessed benchmarking approach instead enables an easy, accessible, dynamic and customised set of metrics for performance measurement to be developed. This will enable a “relevant only” approach for measuring. The crowd sourcing approach will eventually enable the development of dataset groups and categories, what Succar et al. (2012) refers to as filters that will incrementally guide validation and valuation of metrics.

By this we argue that self-assessed crowd sourcing methodology will contribute to the gathering of relevant data; organisations select what is relevant to them for internal benchmarking purposes.

More users successively will lead to a better database, with more valid metrics and more precise measurements which will benefit all users. Furthermore, this approach to benchmarking BIM performance will reduce the risk of leaking sensitive information to a third party since data considered sensitive is regulated in its exposure. Existing frameworks applicable for measuring BIM performance, as mentioned earlier, will either require help from expert consultants or the development of possibly costly in-house know-how and thus are more cumbersome to get started with.

An obstacle to overcome, when applying this methodology of assessment over the whole AECO industry, is the probability for some metrics being easier to score high or fulfil than others. This since there is a risk that the performance of actors in a certain sector will be shown, or indicated, as more mature than others as a result of what metrics are closer, and thus more likely to be used, to the core business and the characteristics for this type of organisation. Hence, it seems reasonable that this methodology and approach to developing BIM performance benchmarks may be a way forward. As a tool for comparing organisations with different abilities and focus throughout the whole industry however, it is unlikely to be applicable in the same way. Rather, it can be used to give a rough estimation, an indication, between the fields which in the long run can provide valuable information about how well a sector is performing BIM in industry context.

As the system is used more, the database will grow in terms of additional new metrics and get more refined and precise as the users automatically validate the metrics. Early adopters or pilot organisations risk suffering inaccurate measuring results as the dataset is developing. This is likely to create barriers to developing the database and pose a threat towards convincing industry actors to adopt it. However, setting up a tool with relevant and versatile default metrics developed through case studies and expert consultation will reduce the chance of this occurring.

## **5. Conclusions**

Development of a framework for self-assessed benchmarking of project based BIM performance with utilisation of crowd sourcing as a method for populating the tool is proposed to be an accessible and cost effective way of evaluating BIM performance. This methodology may reduce unnecessary cost and lead-time as well as avoid sensitive information being exposed to third parties. It can also serve as an efficient tool for comparison between projects given that they will have similar ways of conducting their business and thereby are using similar key metrics. As a method for comparing organisations in varying fields within the AECO industry however, it seems more likely to provide a rough comparison which can be valuable for pin-pointing the weakest capabilities in terms of BIM performance throughout the AECO industry.

To reduce or remove misleading user influence, the tool has to be developed on the foundation of some default metrics. Also, there has to be a certain amount of administrative control in order to adjust eventual misleading data. The dataset hosting the tool is suggested to be developed in accordance with the structure shown in Figure 2.

## 6. Future research

For this methodology to be efficient in procurement situations more research has to be conducted on a foundation of industry case studies. As mentioned earlier in this paper, a starting point and platform of BIM performance default metrics is needed. In order to be useful for the AECO industry as well as internationally applicable, these will be developed through case studies with diverse sectorial as well as regional participants. Another challenge is to define if and by that how weighting of the metrics should be considered. A metric or factor frequently used or assessed might be less important than one of lesser frequency.

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# **Leveraging Customer Satisfaction Using BIM: House Builders' Perspective**

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## **Abstract**

The UK housing industry is growing from the recent recovery of global and the UK economy. More homes are currently required to be built putting a strain on resources. Over the last fourteen years customer satisfaction has been a key performance indicator for the UK government and industry bodies to determine the quality and service that is being provided by house builders. As a result, house builders and professional bodies over these years have strived to improve the level of after sales customer satisfaction. This has led to increased customer satisfaction during the recession. However recent drive for increased productivity levels have reduced customer satisfaction levels; suggesting that the industry needs to use innovation to provide higher levels of customer satisfaction while maintaining productivity. BIM is a new way of working that enables digital representations of the physical and functional characteristics of a facility. BIM intends to supply usable information throughout the lifecycle of a project. The housing industry is beginning to utilise BIM in certain aspects within the business. The implementation of BIM into customer care departments could be the innovation the industry so desperately needs to enhance customer satisfaction. This paper explores how after sale customer satisfaction is evaluated by the UK house builders and their opinion on how BIM can be used to enhance customer satisfaction.

**Keywords:** BIM, Customer Satisfaction, After Sale Customer Care, Volume House Builders, Housing Industry



# 1. Introduction

In 2004, the Barker review was published with a view of globally examining the current Housing Industry. Areas such as economic stability and growth, to environmental considerations were reviewed and the report identified thirty five recommendations in order to develop the current housing industry with the aim of improving customer confidence which was the mechanism to drive house builders to improve customer satisfaction. Further proposal by Callcutt review team (2007) recommends that house builders must achieve customer satisfaction standards within the next two years. However, the Office of Fair Trading (OFT) (2008) points out that even within this broadly competitive sector, many homebuyers experience faults or delays, which includes but not limited to postponements to initial moving in date and faults in new homes. On 1st of April 2010, Consumer Code for Home Builders was made mandatory in the UK and was implemented by the industry's main warranty providers – National House Building Council (NHBC), Premier Guarantee and Local Authority Building Control (LABC). Any house builders using the aforementioned institutions are now required to implement the Consumer Code into their business approach. The code provides guidance to house builders and entails requirements for suitable systems and procedures to ensure it can reliably and accurately meet the commitments on service, procedures and information (Consumer Code for Home Builders, 2010).

From 2006 onwards, there have been extensive market studies that illustrate continuous improvement by house builders relating to customer satisfaction. In a market survey carried out by OFT between 2006 and 2008, an average of 75% of the customer recommended their builder to other potential buyers (OFT, 2008). In March 2015, National Builders Federation (NBF) published further findings based on the 'National New Home Customer Satisfaction Survey'. In comparison, between 2011 and 2012 a 91% of the customers recommended their builder. This suggests that housing developers are striving to improve customer's satisfaction throughout the process. Transparency to the customer through communication and involvement during the construction is now an integral part of the majority of house builders. As such several house builders are starting to offer fundamental customer communication tools to provide them with information on their acquisition from inception to final completion. Conversely many purchasers can still find the process both ambiguous and confusing.

Building Information Modelling (BIM) and related technologies provide an opportunity to improve communication between builder and customers and therefore reduce customer complaints and improve customer confidence. However, many working within house-building do not yet have an awareness of its potential benefits of BIM (NBS, 2013). In order for BIM implementation to be a viable option, house builders must increase their own knowledge and understanding of BIM throughout their business with a view to successfully improve the limited awareness of the potential customers. Therefore a sustainable BIM platform with a user friendly interface for the customer to access during the construction, handover and operation is essential to develop confidence and heighten customer satisfaction. This paper explores how after sale customer services are provided by house builders and the use of Building Information Modelling (BIM) to enhance customer satisfaction.

## 2. Literature review

In 2014 the Lyons housing review was published by the UK Housing Commission. The basis of the report is to determine how best to increase new build units entering the market. Lyons (2014) suggests building at least 243,000 homes a year to keep up with an ever increasing demand from the growing population (see Figure 1). Statistics published by the DCLG indicate that the building industry from 2012-2013 produced 118,540 new builds, which is less than half the recommended units detailed in Lyon's report. Currently the housing market would seem to be on the mend from an incredibly difficult period of its long history. Annual housing starts totalled 137,780 in the 12 months to June 2014, an increase of 22% compared to the year before (Sleight, 2014). Currently developers producing between 500 and 2000+ units yearly contribute to the majority of the overall new build completions yearly figures (Lyons, 2014).

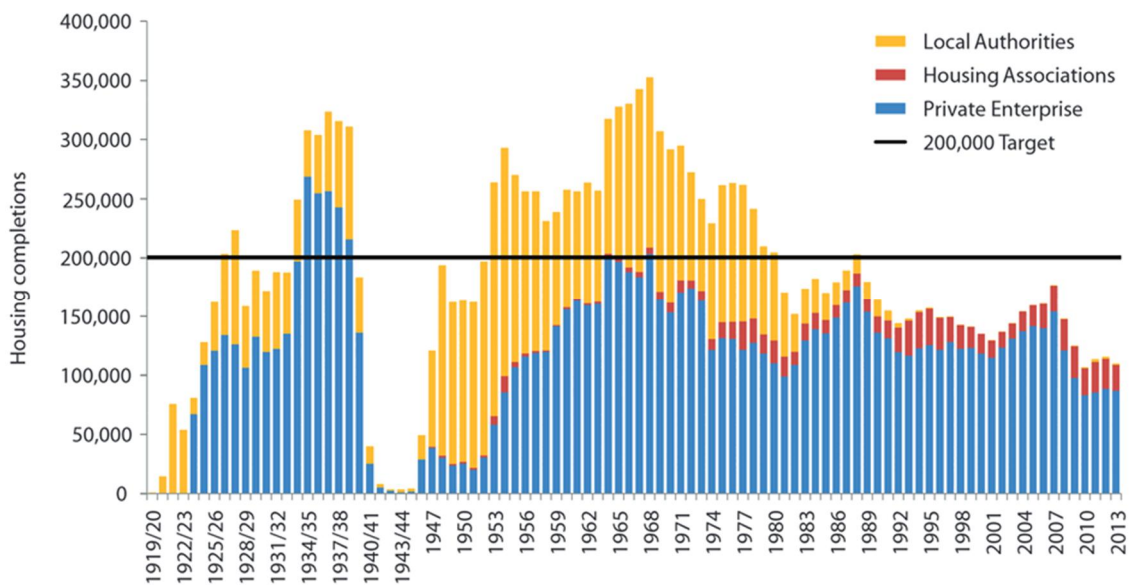


Figure 1: Historic housing completions in the UK (Lyons, 2014)

### 2.1 Customer Satisfaction in Housing

The Latham report recognised the customer as being at the core of the construction process (Latham, 1994). Hayes (2008) suggest that customer satisfaction and perception of quality are labels used to summarise a set of observable actions related to the product or service. A further definition of satisfaction presented by Kotler and Keller (2006) outlining satisfaction as “*person’s feeling of pleasure or disappointment which resulted from comparing a product’s perceived performance or outcome against his/ her expectations*”. Rai (2008) and Churcher (2003) draws the basic formula of customer satisfaction as: “*Customer satisfaction = Customer Perception of the Service Received – Customer Expectation of Customer Service*”. A house is one of the biggest purchases many people will make in their lifetime. Ozaki (2010) argues that “*house builders have increasingly been searching for ways to be more customer focused*” and thus the level of expectation when buying a home and the advertised level of service a house builder provides will elevate the customers’ expectations even higher. Whilst Oliver (1993) considers customer

satisfaction in housing as being a comparison between the customer's pre-purchase expectations and their after purchase perceptions.

The national housing output requirements show that housebuilders need to build more houses every year. The volume of new build unit requirements to meet public demand by house builders will need to rise by half their current output. Therefore challenges set upon the house builders business to achieve these targets such as resource restrictions, availability of material, lack of suitable labour, increasing land values and increase in the requirement to build on brown field developments. This increase in output, could have a potential effect on the customer experience and overall satisfaction of the product. Customer satisfaction of an end product is seen as a direct and reliable indicator of a business' future performance. Cronin and Taylor (1992) suggest customer satisfaction to be important means of obtaining competitive advantage in the market place. Therefore is important for of housebuilders' business growth to improve and maintain customer satisfaction.

Since 2006, Home Builders Federation (HBF) has measured customer satisfaction in the UK which records results from new home customer satisfaction surveys. The surveys were implemented in response to recommendation 32 of the Barker review of housing supply (2004) which stated that the house building industry must demonstrate increased levels of customer satisfaction. In response to the new homes customer satisfaction survey volume house builders have now dedicated customer care teams across their business offices each providing a direct link of information to the customer and responding to all customer complaints to ensure a positive outcome.

To improve customer satisfaction, house builders need to innovate and develop systems to streamline and energise the after sales experience both for the customer and the internal customer care team and therefore to improve follow-ups on incomplete items. According to CA Design services (2001) *"customer satisfaction comes from exceeding expectations, that means not just meeting the basic need for a building, but also providing services that meet and exceed their specific individual requirements, as a result delivering something extra"*. There are anecdotal evidence that suggests BIM as an approach to improving customer satisfaction. For this the industry needs a systemic change rather than a visualisation tool. Hence, it is important to understand what BIM and its potential use.

## **2.2 What is BIM?**

Building Information Modelling, BIM is set to modernise the construction industry. According to Gardiner (2013) BIM is a way of working that allows virtual 3D models of buildings to be created by designers and contractors that can be shared with an entire project team. Information about objects and products that goes into constructing and maintaining a building can also be added to the model. NHBC (2013) suggests that *"BIM is a process that improves the efficiency of organising and distributing information - or data - that is generated during the design and construction of buildings and infrastructure"*.

RIBA proclaims BIM to be the, “*the process of generating and managing data about the building during its lifecycle*”. (RIBA insight, 2014). Which suggests BIM offers increased productivity in design and construction from the data it produces and holds. It delivers value through creation, collation and exchange of shared models and corresponding intelligent structured data. BIM can assist to close the gap between stages with shared data sets while allowing transparency. From these BIM can be understood as a different way of thinking and working by sharing, and effectively working on, a common information pool. BIM involves building a digital prototype of the model and simulating it in a digital world. This suggests that BIM must be promoted as a delivery system to produce an intelligent model that can hold physical attributes that could be used for overall design decision making.

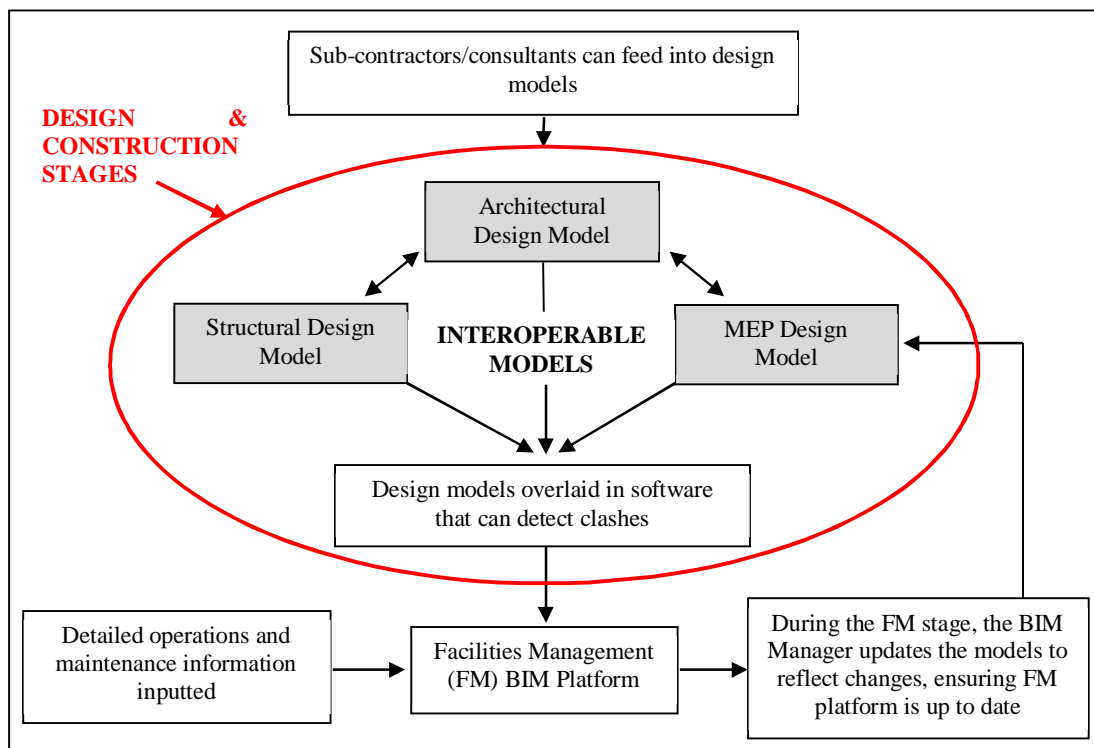


Figure 2: Interoperable BIM Process

The introduction of BIM has been brought about due to a requirement for increased sustainability and productivity within the construction industry (BIS, 2011). As stated by BIS (2011) there are four levels of BIM adoption, from 0-3, depending on how models are managed and the collaborative working practices are adopted. Level 2 essentially requires teams to be working collaboratively with 3D BIM (see Figure 2), however with no obligation for the 4D programme, 5D cost and operation elements to be incorporated within the model (Isikdag, Underwood, & Kuruoglu, 2012).

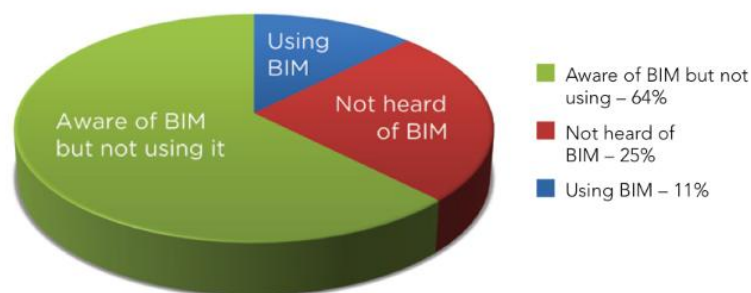
## 2.3 House Builder's and BIM

As suggested by Saxon (2013) “*The arrival of BIM since the early 2000s has been USA- led*”. A study by National Building Specification (NBS), has made yearly information available since 2011. The reports suggest improvement in awareness and use of BIM across the industry.

However, a recent report by the NHBC indicates that the majority of the major house builders in the UK are currently not engaged in BIM (NHBC, 2013) (see figure 3). This would suggest that due to the amount of awareness in the industry, it does not seem to potentially be in House Builders' vision for the foreseeable future.

Furthermore, the benefits that BIM can provide to house builders are not adequately researched. There are challenges that come hand in hand with the implementation of BIM as an integral part of a business including technological and business process integration, as with any enhancement. The effect of making a momentous step when resources are at their most stretched as demand is out weighing supply both from a materials and customers point of view.

*Figure 3: House builders' engagement with BIM (NHBC, 2013)*



Organisations are cautiously starting to move forward and upscale operations from the recent recession. BIM is seen as similar to move to drafting on tracing paper to using 2D. As proclaimed by CA Design services (2011), “BIM by its nature is client-centric” and can, used well, deliver better services. Including:

- Provide accurate documents.
- Improve communication between the customer and the house builder.
- Reduce errors and coordination issues leading to cost saving to the house builder.
- Inform clients with visual aids and represent the final product to avoid any unwanted features.
- Produce a product that is less defective and thus increases the satisfaction of the customer.

Over the last 15 years customer satisfaction has been a major factor for a house builder and has been increasing year on year. However the house builder approaches a potential tipping point and will require systems of innovation in place that can manage to ease pressure on personnel and resources to allow them to get on with building houses to a high standard.

BIM could be that revolutionary system by:

- Providing real time information to customer on build completion date.
- Storing of information in one place including house designs from wall construction to boiler type to tile manufacturer. Information includes contracts, Warranties and itemise details of what parts of house is under warranty and terms, from reservation to after sales care.

- Storing relevant underlying data (e.g., material, dimension, cost, energy performance, and even product availability) that allow builders, designers, and buyers to make informed decisions (See figure 2).
- Allowing access to site production team and update model house types where clashes have occurred in design.
- Allowing customers to pinpoint defects to ensure the right after sale support and relevant trade visits to complete the work.
- Providing the customer the option to improve design and / or functionality that can be passed to architect for review of current customer living needs and requirements.

■ Briefing documents	■ Costing/supplier enquiries
■ General correspondence	■ Quotations
■ Feasibility studies	■ Requests For Information (RFIs)
■ Utilities and infrastructure reports	■ Tender/contract documents
■ Site surveys	■ Commissioning sheets
■ Ecology studies	■ Working drawings
■ Design drawings	■ O&M manuals
■ Specifications	■ Statutory certificates
■ Schedules	■ Local authority submissions and approvals
■ Programmes	■ Financial management

*Figure 4: Information types for house builders (NHBC, 2013)*

These points are by no means exhaustive; for implementation a clear delineation is essential to appreciate what is needed and to consequently support a strategy for operation. BIM entails an adjustment to a collaborative and autonomous way of managerial philosophy to essentially enrich the corporate benefits previously detailed. Suggesting BIM is more than just an enhancement of an existing software package but more of a sophisticated computer software creating a virtual model that can benefit all professionals in the lifecycle process. With BIM customer care departments can potentially lead to increased customer satisfaction and transparency.

### 3. Research methodology

Research methodology refers to the overall approach to the design process from the theoretical underpinnings to the collection and analysis of the data (Collins and Hussey, 2003). For this research, fourteen semi structured interviews were conducted with customer care professionals working in Volume House Builder organisations to gather qualitative data. Interview questions were divided into two sections, a) to understand the current process of after sales customer care b) potential influence of BIM on customer satisfaction. Initial pilot studies prompted further research into a software package that was used by many respondents. It was identified that the current after sales system providers were developing BIM for integration into their current software. During the interviews open questions were used. These open questions allowed the development of an open forum, in order to capture the opinion of the interviewees and to develop a meaningful understanding of how current systems work within the organisation and as discussed above, how BIM would be an added benefit rather than a system overhaul.

## 4. Findings and Discussion

Customer care ratings produced by the NHBC/HBF are very significant to how potential customers perceive them and how well developments sell. Most of the interviewees indicated that house builders currently have business objectives in place to improve after sales customer satisfaction. Plumbing, drainage, electrical issues and painting were suggested as the main complaints/issues received after sale. Most of the interviewees confirmed that a similar system is currently used within the customer care department. Interviewee 1 stated that the current *'system is very good and is used universally by all of our regions'*. This links all departments under one umbrella from land acquisition, feasibility studies, design, procurement, build programme, payments, sales, and customer service and after care. *'It's a company package that we bolt on to and not just specific to our department'* as interviewee 3 proclaimed.

This customer care system starts when a customer advisor receives a call/text/email from the customer. Then the customer care advisor contacts the customer and discusses the issue. From the information provided, the advisor can find the property address and identify a contractor to complete that work. A defect report is then sent to the contractor and the system keeps a log of initial customer contact. The contractor is normally given three days to contact the customer and arrange an appointment with the customer to complete the work. The contractor then updates the advisor who then contacts the customer to ensure that they are satisfied with the ongoing process.

All interviewees discussed the complex communication lines between four or more parties when dealing with issues. It was a common theme from the interviews that communications become very diverse as all parties can talk to each other at different times, agreeing different arrangements. All interviewees confirmed that arrangements between two parties are very rarely communicated effectively to all other parties. This leads to a very complicated and chaotic approach, and parties can be left unsure of what is required of them and when. This needs a better communication system incorporated into the customer care process. Interviews also advocated for increased support from subcontractors and a better user friendly system to improve after sale services.

The interviewees recognised the use of BIM to avoid errors in communication and help support the customer care department in trying to bring everyone together. House builders are starting to develop large 1000 unit parcels of land. To speed up the development of these parcels and to spread risk, multiple developers work together as a consortium. With this in mind, house builders need to implement a system that not only allows communication between participants during the construction stage but also for after sales operations. This means house builders need a systemic change to their operations. BIM can improve communication between the clients and house builders and can reduce number of snags (defects). BIM models hold information such as who installed the building element, supplier details, warranties, insurances and all building components operating user manuals about a specific property. Interviewees suggested that the system with the 3D user interface could provide diagnostic tools to enable users to resolve the issues themselves with step by step guides. These models could provide a maintenance plan for the owner providing updates on when maintenance is required such as boiler check and electric test. This would enable more efficient fault detection and reduce customer complains. Most of the

interviewees suggested that BIM could help to decrease delivery time as they can communicate with customers, contractors and suppliers more efficiently. BIM makes it possible to integrate information from different disciplines in different phases of the building process enabling a central location for communication links between all departments within the business as well as the customer. Current systems and processes are not equipped to deal with the increased requirements of the industry. BIM could be utilised to drive and improve customer satisfaction across the business. A strong company brand with efficient processes through the business can lead to increased employee satisfaction while being able to attract the best talent in the market further increasing the quality and satisfaction the customer receive.

The significant barrier is the implementation of BIM into current house builder software infrastructure. As the majority of volume house builders use a similar system it would be difficult to change and introduce a new one. Findings suggests that BIM is being designed into the current system and therefore would not be an onerous or difficult process to integrate. This would be beneficial to the customer care department as the current system is not designed specifically for efficient work processes.

## **5. Conclusion**

The research has attempted to establish an understanding of what customer satisfaction means to a house builder and the current systems they have in place to be able to satisfy their customers. House builders are pushed to produce more houses across the nation. However this could affect customer satisfaction levels in the industry. There is significant need for innovation and improved systems to centralise asset data and provide customers with services that exceeds their expectations to improve and maintain customer satisfaction. BIM could be the innovative tool providing real-time information to the clients and to streamline aftersales operations.

Findings suggest that housebuilders are reluctant to change their current aftersales systems. However there is an overwhelming suggestion to integrate BIM as part of the current aftersales system, especially with the provision of online 3D model based graphical user interface to improve communication. This means house builders need to integrate BIM across the organisation and ensure the use of BIM throughout the lifecycle of a building. However, further research is required in understanding how the existing system and BIM can be effectively integrated throughout the lifecycle of a building to improve customer satisfaction.

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# **Towards a Framework to Understand Multidisciplinarity in BIM Context - Education to Teamwork**

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## **Abstract**

Construction projects by their very nature, have always involved the cooperation of various disciplines. Typically, construction projects are unique and large, comprising of many phases, requiring major investment and activities that are spread amongst multiple disciplines. Active collaboration and effective teamwork between project participants is thus considered central and critical. Multidisciplinarity in construction projects however requires careful investigation of team selection that is based upon individual skills and competences. The industry today is inclining towards the adaptive use of model-based processes and technologies namely building information modelling (BIM), and there is a need of BIM competent workforce to support these ongoing changes. Study of the impact what different levels of BIM skills and competences an individual has in multidisciplinary team selection and how the multidisciplinarity of the BIM team works is a relatively new area of interest for researchers in academia and industry alike. This paper thus proposes a conceptual framework for assessing multidisciplinarity in BIM context.

**Keywords:** Add up to five keywords here, separated by commas

# 1. Introduction

Construction projects are unique by nature and include a wide variety of disciplines, individuals and organizations working towards a common goal. Traditional methods of construction project planning, designing and execution have been fragmented across multiple firms and disciplines. Effective and efficient collaboration amongst the project participants is seen as critical and beneficial for projects, leading to greater efficiency, quality, and hence, increased productivity for the construction industry as a whole. Today, we see different methods, processes and technologies being actively implemented to support collaborative ways of working, such as building information modelling (BIM).

BIM is considered a disruptive technology that provides a new way of managing the design and construction of projects with wide support for collaboration (Eastman et al., 2008; Gu et al., 2008; Hardin, 2009; Arayici, Egbu, & Coates, 2012, Yalcinkaya & Singh, 2015). BIM processes and technologies are increasingly being implemented at varying levels across the world. There is currently a rapid growth in BIM adoption and implementations in construction projects of different scales and nature. According to the literature, there has been 21% increase in BIM adoption from 2007 to 2009 in North America (McGraw Hill, 2009); 12% increase from 2009 to 2010 in Europe (McGraw Hill, 2010); 41% increase from 2010 to 2014 in UK (NBS, 2015).

One of the basic constituents of successful BIM implementation is efficient collaboration amongst project participants and the multidisciplinary of the team involved. While multidisciplinary teams are considered important, there has been very little conceptual and methodological support (1) to objectively assess and compare multidisciplinary of two or more individuals or teams, (2) to measure the impact of individual expertise on multidisciplinary teams, and (3) to define which of the many combinations of multidisciplinary skills is suited to a given context. Thus this paper aims to present a conceptual framework that could be further developed to understand multidisciplinary in BIM context.

## 2. Background

### 2.1 Multidisciplinary approach

Creating teams made up of varying disciplines, in general, facilitates the resolution of complex problems by generating new and creative solutions. The Oxford dictionary defines the term “multidisciplinary” as “combining or involving several academic disciplines or professional specializations in an approach to a topic or problem.” Various sources in literature identify the importance of multidisciplinary in teamwork. Choi & Pak (2006) define the objective of multidisciplinary approach as “to resolve real world or complex problems (...and) to provide different perspectives on problems”. Similarly, Cross (2004) highlights the importance of multidisciplinary as an approach to increase the possible generation of creative solutions through interconnection of interdisciplinary knowledge of participants.

Multidisciplinary teams, on one hand are required and beneficial for solving critically important and complex problems, while on other hand can also provide new dimensions towards innovative knowledge generation and creation. Individual expertise, skills and competencies have direct impact on dynamics of multidisciplinary in teamwork and so a balanced synthesis amongst required fields is important for effective multidisciplinary team building. Given the complexity of social, technical and process variables when working as part of a team in a construction project, it is important to gain an understanding of what multidisciplinary means in the specific context of AEC industry. This understanding is particularly necessary given the traditionally silo mentality that exists between the engineering disciplines.

## **2.2 Multidisciplinary in construction projects**

Construction projects by their very nature, have always involved the cooperation of various disciplines. Typically, construction projects are unique and large, comprising of many phases and requiring major investment. Output of a construction project is a collective effort and goal of multiple disciplines involved. Due to the fragmented nature of activities, active collaboration and teamwork is being considered as essential today in construction projects.

A significant factor accounting for the fragmentation of the AEC industry is organizational divisions due to the fact that the industry is made up almost entirely of SMEs (small to medium enterprises) many of these acting in a single discipline. The annual report on SMEs by the European Commission concluded that between 2012 and 2013, 90 % of total people employed in the European construction sector work in SMEs and furthermore SMEs contributed €400 billion to the construction sector out of the €485 billion total value added production (Gagliardi et al., 2013). Given that such a large percentage of the industry is made up of small to medium organizations, many of which are mono-disciplinary, it becomes imperative that exchange of information and skills between organizations be explored in greater depth to gain an understanding of multidisciplinary.

Various tools, processes and technologies have been developed and implemented to facilitate, support and enhance multidisciplinary collaboration. Contractual models such as PPP (Private Public Partnerships), IPD (Integrated Project Delivery), Alliance contracts and partnering encourage shared interest in project success by giving the participants a vested interest/ownership. Further to the development of integrated contractual arrangements to encourage multidisciplinary collaboration and partnering, various tools and methods have been developed to improve the capabilities of the organizations involved. Building Information Modelling (BIM), BIG room (BR) and Knotworking (KW) are amongst a number of which have been developed to facilitate collaboration in multidisciplinary projects. However, all these approaches are enablers to create multi-disciplinary environments, but they by themselves do not provide any decision support on how to compose a balanced multi-disciplinary team.

## 2.3 BIM and multidisciplinary

BIM is widely accepted as a revolutionary technology, and potentially revolutionary socio-technical approach for collaboration in construction projects. BIM adoption, implementations and its benefits for construction projects has been widely discussed and researched. Active collaboration between the project participants and smooth data exchange between the tools they utilize is considered a key to successful BIM implementation. Thus, adaptive use of BIM not only requires but also supports multidisciplinary.

### 2.3.1 How BIM influences/ supports multidisciplinary

BIM support multidisciplinary at individual as well as team level. Some of the aspects of BIM supporting multidisciplinary are listed as follows:

- **BIM and multidisciplinary communication** - Koutsikouri et al., (2006) state that “success in a multidisciplinary practice depends on (...) the quality of interactions between team members”. Recognizing that a BIM approach facilitates better quality interactions between team members it surmises that BIM adoption is ultimately positive as a multidisciplinary team.
- **3D coordination** - The majority of interest and focus (with regard to BIM approach) is in the area of 3D coordination. According to Jung and Lee (2015) 85% of AEC companies surveyed considered this to be the most important utilization of BIM today.
- **Common data environment** - Single file concept of integrated BIM for multidisciplinary data exchange.
- **BIM as a knowledge creation and exchange platform** - integrated domain specific knowledge.
- **BIM as a tool for multidisciplinary input** - BIM applications as knowledge-based systems have a lot of integrated interdisciplinary and organizational knowledge. An architect with limited experience in energy modeling can still run preliminary energy simulations to know how his/her design is performing with regard to energy.
- **Design authoring** - Integrated teamwork possibilities within domain specific BIM environments for informed decision making.

### 2.3.2 How BIM requires multidisciplinary

As discussed earlier, BIM technologies, their adoption and implementation requires collaborative teamwork and processes. Development of new roles and need of new competencies for disciplines suggest new approaches and requirements for multidisciplinary collaboration amongst the project participants. As an example, the job of BIM coordinator/BIM manager has become a common role only in the past approx. 5-10 years to support coordination and management of multidisciplinary team and activities spread among different disciplines. Therefore, BIM requires multidisciplinary skills and knowledge both at individual and team level.

- Individuals not only need to know about their own discipline but also need to have BIM skills and knowledge. i.e. domain knowledge as well as BIM knowledge; and
- The team as a whole not only needs to know about the domain areas, but also needs to know how to work together and collaborate in a BIM project, i.e. task knowledge as well as teamwork knowledge, including teamwork in the context of BIM.

Therefore, it is desirable to understand the balance of domain vs BIM knowledge that is required at individual levels, and similarly, what is the balance of task vs team knowledge needed at team level. Currently, there are no methodological approaches to assess or understand these requirements.

## **2.4 Need for a common framework for multidisciplinary assessment**

With increase in BIM adoption and implementations, the need of multidisciplinary in teams has been highlighted as a core element in BIM based projects. There is a need for processes and methods to assess multidisciplinary both at individual and team level, for smooth BIM transition and to support the technological changes brought about by BIM. We furthermore highlight the need of a common framework for multidisciplinary assessment for the following reasons at individual level and team level:

### **2.4.1 Individual level:**

There is lack of BIM capability assessment criteria, standards or standardized accreditation. As diverse BIM tools and technologies are present, there is not yet any common system for assessing individual BIM competencies and guidelines to support the level of BIM expertise needed. There is much variance in individual BIM competences dependent upon level of BIM knowledge, BIM skills and the level of expertise required for a project of differing types. Assessment of individual BIM tool competences can be seen emerging for specific BIM applications conducted primarily by private industry such as software vendors. These individual level of competences are important, however, requirements vary according to the project type, location and diversity of BIM tool utilization. No system defining these levels or competences has yet been developed.

### **2.4.2 Team level:**

The level of BIM application competences in accordance with the level of domain expertise have several possible combinations and thus have direct impact on the level of team competence and multidisciplinary in teams. Not only is the individual BIM competence assessment (individual BIM competent profile) missing, a system for selecting a BIM competent team based on the skills required for a project, does not exist (Multidisciplinary team profile).

We see that a common framework for understanding multidisciplinary at individual and team level would be able to assist in the composition of multidisciplinary project teams. It is the view of the authors that developing a common framework to measure and compare multidisciplinary levels in the AEC industry both at individual and team level could provide a tool, method and system for team selection. The core concept of development towards a framework to understand multidisciplinary in BIM context is thus discussed and presented. Furthermore, we see an opportunity for utilizing the framework for various purposes and needs in different fields such as recruiting and employment (comparison of candidates), development of BIM educational activities and programs (aligned to industry requirements of graduates) as well as to facilitate team selection criteria for BIM based projects.

### 3. Conceptual outline for the multidisciplinary framework

Different maturity matrix models have been developed over time that claim to precisely quantify BIM maturities of people (individual and team level), processes (organizational level) and product (project level). Amongst the present BIM maturity toolsets, organizational and project level maturity are much more focused; whereas only “BIMe” is present for assessing individual as well as team maturity as shown in Figure 1.

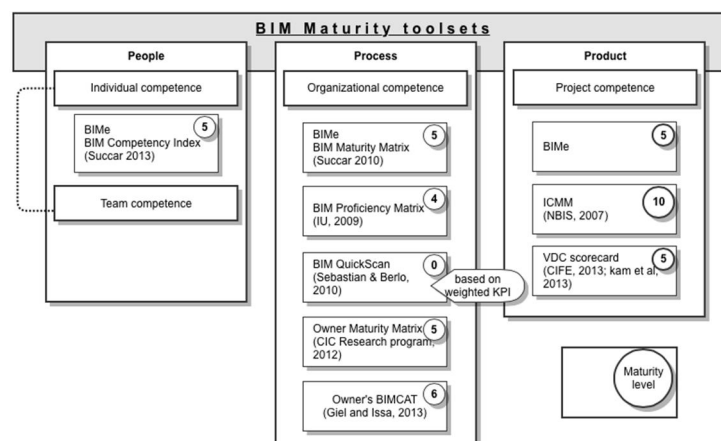


Figure 1: BIM maturity tool comparison (adopted from Geil and McCuen, 2014)

Our conceptual focus goes beyond assessing the maturity levels to understanding the BIM competence combinations and the varying level of combination possibilities that would help in optimizing multidisciplinary team formation and see its impact on the possible team compositions. Thus, rather than focusing only on assessing a team’s maturity, we also intend to develop methodologies of profiling so that we can understand the desirable composition. That is, out of the numerous permutations and combinations possible for skills and expertise levels, which combinations are desirable and suitable to a specific context is needed, Figure 2.



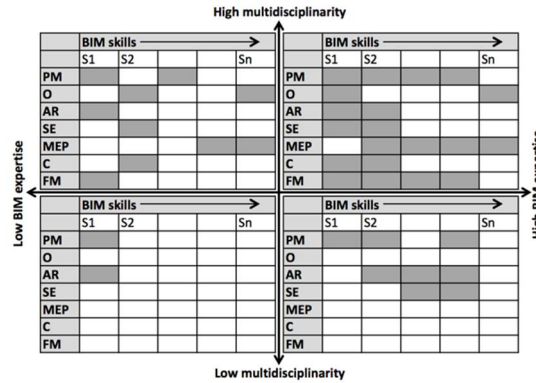


Figure 2: Individual and team profiles as a combination of disciplines and expertise levels aligned with BIM skills (Adopted from Singh and Casakin 2015)

As an analogy, you do not get the best football team by putting together a team of all the best players in different positions. A good team has a balance of top class players, good players and promising rookies, who can still collaborate to potentially give the best result. How do we achieve the same level of team management in BIM projects? How do we profile the team members and team for their various competences, and identify areas for improvement at both the individual and team levels?

### 3.1 Individual profile - Individual BIM competent discipline

Project participants today require adequate BIM knowledge and skills of tools and processes along with the discipline specific knowledge and processes. We term the disciplines as “individual BIM competent discipline” (in generalized form “Dn”). This integrated BIM competent discipline profile has different variances (D1a, D1b,...D1n as represented in Figure 3) depending upon the level of expertise and knowledge an individual has both in their own disciplinary field as well as with BIM.

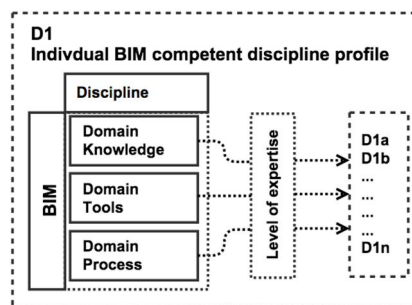


Figure. 3 – Individual BIM competent discipline profile formation

As the use of BIM varies with project type and scope, primary and secondary BIM uses from Kreider et al (2010) (Appendix 1) has been followed and defined as the 25 BIM skill set in this paper. Common BIM requirements (CoBIM, 2012) series has been extensively followed in this paper to develop the project participants and the roles needed for a BIM project. The identified

roles and responsibilities in a typical BIM project are listed as seven disciplines, namely - project manager (PM), owner (O), Architect (AR), Structural engineer (SE), Mechanical electrical and plumbing engineer (MEP), Contractor (C) and Facility manager (FM). We are aware of emerging new roles of BIM coordinator/manager (Lehtinen, 2010), however for this study we include it as a role conducted by a project manager.

Different maturity matrices use a range of 4-10 maturity level as presented in Figure 1. To make it simple at this conceptual stage, we follow the approach of Succar & Kassem (2015) and adopt five level of maturity levels represented as level 1: low, level 2: medium-low, level 3: medium, level 4: medium-high, and level 5: high. A baseline standard thus could be easily adopted in an individual, organizational as well as national level to support and define the minimum BIM competence required. For example, if a standard baseline of a PM is set as of minimum requirement of level 4, presented scenario in Figure 4, would have a direct approach for the preferable PM with level 4 competence.

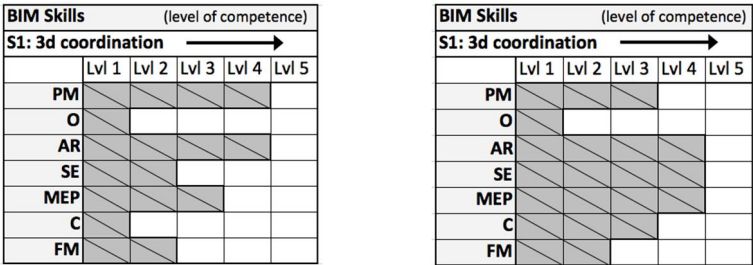


Figure 4 - Possible individual BIM skill profile depicting a possible multidisciplinary team composition for 3d coordination skill

### 3.2 Multidisciplinary and BIM expertise - Team profile

The variance of individual BIM competent discipline profile provides the possibilities of generating different combinations of multidisciplinary teams. The teams thus generated could be compared with benchmarked profile of a multidisciplinary team to depict the best possible solution based on the project as presented in Figure 5.

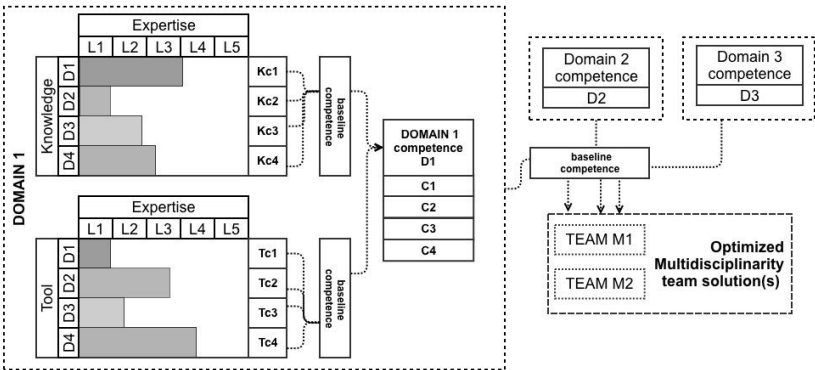


Figure 5: Optimized multidisciplinary team solutions

Thus, the possible combinations of multidisciplinary and levels of BIM expertise is large and so there is very rare evidence about how the multidisciplinary of team and individual BIM competences influence the team performance.

## **4. Future work / Discussion**

The authors in near future aim to implement the presented conceptual framework for various scenarios ranging from education to teamwork in AEC projects that will help in validating and giving more rigorous results in practical scenarios. BIM skills identified will be filtered for the various planned case projects and thus applied to validate its usefulness.

### **4.1 Mapping individual skills and profiles**

Multiple approaches to creating and validating the multidisciplinary assessment framework will be applied. Building on the existing research and industry surveys conducted in various parts of the world (e.g. McGraw Hill, 2009, 2010; Kreider et al., 2010; Finne et al., 2013; NBS 2015), this research will collect further data within classroom settings, offices and recruitment agencies. The questionnaires for collecting data will begin with an open ended structure, where respondents will be asked to identify the skills they deem most important for their role. In the next phase, a list of skills will be given for respondents to choose from and rank in order of their importance. In the final phase, for each of the shortlisted skills ranked high by the participants, they will be required to use a Likert scale (varying level of scales will be implemented based upon the case projects) to mark the level of expertise desirable in that skill set. Thus, the questionnaire will create a matrix of the number of skills and the level of expertise in each of the skill sets. In addition, experimental set-ups with simulated BIM projects will be used to test the applicability of the framework.

### **4.2 Validate the mapping of skills and profiles**

In order to validate the proposed conceptual framework, future work may test the framework in a multidisciplinary setting, observing skills as they are acquired and measuring the effects on the profile of the group and, of course, its performance at the given task. Therefore, the authors will implement it in a workshop bringing together design students from various backgrounds to simulate a BIM based construction project scenario. The students will simulate their roles resembling a real construction project. The workshop has been planned as a small structure that should, for its completion, bring together a number of trades and construction methods. The team will utilize BIM for the design and construction of the structure. In order to simulate roles more accurately, BIM dimensions focused includes digital project controlling in order to track and analyze progress of the construction activities and phases.

Based on the conceptual framework presented, Figure 6 shows the baseline for required project participants and the BIM skills focusing the planned construction workshop. The framework suits the type of project and group of disciplines. The BIM competences are rated out in Likert scale of range 1-5 to generate the baseline profile for the team.

Skills	Project roles	Site Manager (x1)	Design Manager (x1)	BIM technician (x2)	Carpenter (x3)	General Labour (x4)
	BIM use					
S1	3D coordination					
S2	Design Reviews					
S3	Design Authoring					
S5	Existing Conditions Modeling					
S8	Phase Planning (4d Modelling)					
S10	Site Utilization Planning					
S11	Site Analysis					
S14	Cost Estimation					
S22	Digital Fabrication					

*Figure 6 - BIM skills required of workshop participants*

As a method of benchmarking, the framework prepared is planned to be distributed within industry as questionnaires for further validation of the BIM competences specific to Finnish requirements. Respondents would be instructed to fill out the framework with the desired range and level of BIM skills needed for the team and project. Having these industry requirements as a benchmark, the data collection will be aligned with the participants of the workshop. The participants during the workshop will fill in their skills into the framework at two levels - before the workshop to map expectations and understandings of the participants and after the commencement of the workshop to validate the usefulness of implementation. With the perceived usefulness of the implementation, authors seek to furthermore assess the impact in BIM learning. Furthermore, we hypothesize that these types of collaborative approaches of working in a multidisciplinary environment generates new skills and assist in learning from each other while simultaneously completing the project more effectively.

## 5. Conclusion

It is agreed in the literature that multidisciplinary collaboration in projects leads to the generation of creative solutions for complex problems. Global increase in BIM adoption and its diversified implementations have shown that BIM is here to stay and will be a de-facto attribute for the professionals. Various researches and industry implementations suggest that success of BIM based projects require integrated multidisciplinary team and active collaboration amongst the individuals. However, the level of BIM competencies and its impact on the multidisciplinary team formation and its effectiveness is still a very young research area. Authors believe that the framework presented will help in assessing BIM competences at individual as well as team level. It will furthermore guide towards development of systems and method to both assess and support on how to compose a balanced multi-disciplinary team.

## 6. Reference

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**Appendix 1 - BIM skills based upon BIM use frequency and benefit with respect to rank order from Kreider, et al., (2010)**

<i>Skills</i>	<i>BIM use</i>	<i>Description</i>	<i>Discipline</i>
<i>S1</i>	<i>3D coordination</i>	<i>A process in which Clash Detection software is used during the coordination process to determine field conflicts by comparing 3D models of building systems.</i>	<i>PM, AR, SE, MEP, C</i>
<i>S2</i>	<i>Design Reviews</i>	<i>A process in which stakeholders view a 3D model and provide their feedbacks to validate multiple design aspects.</i>	<i>PM, AR, SE, MEP, C</i>
<i>S3</i>	<i>Design Authoring</i>	<i>A process in which 3D software is used to develop a Building Information Model based on criteria that is important to the translation of the building's design.</i>	<i>PM, AR, SE, MEP, C</i>
<i>S4</i>	<i>Construction System Design</i>	<i>A process in which 3D System Design Software is used to design and analyze the construction of a complex building system (e.g. form work, glazing, tie-backs, etc.) in order to increase planning.</i>	<i>PM, O, AR, SE, MEP, C</i>
<i>S5</i>	<i>Existing Conditions Modeling</i>	<i>A process in which a project team develops a 3D model of the existing conditions for a site, facilities on a site, or a specific area within a facility.</i>	<i>PM, AR</i>
<i>S6</i>	<i>3D control and Planning</i>	<i>A process that utilizes an information model to layout facility assemblies or automate control of equipment's movement and location.</i>	<i>PM, C, FM</i>
<i>S7</i>	<i>Programming</i>	<i>A process in which a spatial program is used to efficiently and accurately assess design performance in regard to spatial requirements.</i>	<i>PM, O, AR</i>
<i>S8</i>	<i>Phase Planning (4d Modelling)</i>	<i>A process in which a 4D model (3D models with the added dimension of time) is utilized to effectively plan the phased occupancy in a renovation, retrofit, addition, or to show the construction sequence and space requirements on a building site.</i>	<i>PM, AR, SE, MEP, C</i>
<i>S9</i>	<i>Record Modelling</i>	<i>Record Modeling is the process used to depict an accurate representation of the physical conditions, environment, and assets of a facility. The record model should, at a minimum, contain information relating to the main architectural, structural, and MEP elements.</i>	<i>PM, FM</i>
<i>S10</i>	<i>Site Utilization Planning</i>	<i>A process in which BIM is used to graphically represent both permanent and temporary facilities on site during multiple phases of the construction process. It may also be linked with the construction activity schedule to convey space and sequencing requirements.</i>	<i>PM, AR, C</i>
<i>S11</i>	<i>Site Analysis</i>	<i>A process in which BIM/GIS tools are used to evaluate properties in a given area to determine the most optimal site location for a future project.</i>	<i>AR</i>

S12	Structural Analysis	A process in which analytical modeling software utilizes the BIM design authoring model so to determine the behavior of a given structural system.	SE
S13	Energy Analysis	The BIM Use of Facility Energy Analysis is a process in the facility design phase which one or more building energy simulation programs use a properly adjusted BIM model to conduct energy assessments for the current building design.	MEP
S14	Cost Estimation	A process in which BIM can be used to assist in the generation of accurate quantity take-offs and cost estimates throughout the lifecycle of a project.	AR, SE, MEP, C, FM
S15	Sustainability LEED Evaluation	A process in which a BIM project is evaluated based on LEED or other sustainable criteria.	AR, MEP
S16	Building Systems Analysis	A process that measures how a building's performance compares to the specified design. This includes how the mechanical system operates and how much energy a building uses.	MEP
S17	Space management/tracking	A process in which BIM is utilized to effectively distribute, manage, and track appropriate spaces and related resources within a facility.	PM, AR, FM
S18	Mechanical Analysis	A process in which intelligent modeling software uses the BIM model to determine the most effective engineering method based on design specifications.	MEP
S19	Code Validation	A process in which code validation software is utilized to check the model parameters against project specific codes.	PM, AR
S20	Lighting Analysis	A process in which intelligent modeling software uses the BIM model to determine the most effective engineering method based on design specifications.	MEP
S21	Other Engineering Analysis	A process in which intelligent modeling software uses the BIM model to determine the most effective engineering method based on design specifications.	AR, SE, MEP
S22	Digital Fabrication	A process that uses digitized information to facilitate the fabrication of construction materials or assemblies. Some uses of digital fabrication can be seen in sheet metal fabrication, structural steel fabrication, pipe cutting, prototyping for design intent reviews etc.	AR, SE, C
S23	Asset Management	A process in which an organized management system is bi-directionally linked to a record model to efficiently aid in the maintenance and operation of a facility and its assets.	O, FM
S24	Building Maintenance Scheduling	A process in which the functionality of the building structure (walls, floors, roof, etc.) and equipment serving the building (mechanical, electrical, plumbing, etc.) are maintained over the operational life of a facility.	FM



<i>S25</i>	<i>Disaster Planning</i>	<i>A process in which emergency responders would have access to critical building information in the form of a model and information system.</i>	<i>AR, FM</i>
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# Is the lack of a common BIM vision between clients and contractors a cause for concern?

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## ABSTRACT

A post-positivist methodology is employed to answer the question posed as to whether or not the lack of a common vision about BIM poses a problem for adoption in the built environment. The context is set by reviewing both the established benefits of BIM and the collaborative and other benefits it fosters. A sample of nine recent adopters of level 2 BIM were interviewed, including clients, architects, designers, first and second tier contractors. Their responses provided qualitative data for examination and interrogation. The population was asked about their definition of BIM, the positives and drawbacks they perceive over a series of questions. In this way, and through the examination of comments from the respondents, it was possible to examine the divergent views on what BIM represents to the UK construction industry in 2015. The key finding is that complimentary views existed notwithstanding the different emphasis placed on BIM by the respondents.

Keywords: Building Information Modelling, Collaboration, Early Contractor Involvement, Partnering.

## 1. INTRODUCTION

If Building Information Modelling (BIM) is to succeed then the take up amongst all stakeholders at all levels must be accelerated. The University of the West of England has experimented with achieving improved take up by encouraging best practice by embedding the knowledge and learning derived from academic institutions within commercial organisations. In this context, collaborative placements were arranged in 2015 whereby Masters Students on the BIM master's programme were able to assess and align the business case and needs of the participants and elucidate the same in a BIM Execution Plan.

The notion behind the placements was that the students would become "BIM champions" for the firms taking them. The students acted as a focal point for BIM implementation and were able to deliver any projects set for them by the business owners. The students were also present to listen as a sounding board for any observations about BIM obstacles and drawbacks being experienced. Their time at the placement culminated in their interviewing of key staff which

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has provided the data for this paper. Views were gathered on the wider context of BIM adoption and the perceived barriers to entry and thoughts for the future. These views became the main data set on which this paper is based.

## 2. CONTEXT

In the United Kingdom, many commentators have adopted the definition coined by Keith Snook former RIBA director of research; *"Building Information Modelling is a digital representation of physical and functional characteristics of a facility creating a shared knowledge resource for information about it forming a reliable basis for decisions during its life cycle, from earliest conception to demolition."* It requires, therefore, contractors, sub-contractors, lead designers, architects, project managers and designers to work together and share information.

BIM maturity and adoption varies between industry sectors and countries. More contractors are using BIM than architects (McGraw-Hill Construction, 2012). 37% of engineers in Western Europe use BIM, versus 42% in North America, 48% of architects who use BIM consider themselves advanced or expert (McGraw-Hill, 2010). Notwithstanding these statistics, a recent study concluded that there is a great lack of well-educated and trained BIM professionals (Wong & Fan, 2013).

The UK Cabinet Office has published a construction strategy article that requires the submission of a fully collaborative 3D BIM (with all project and asset information, documentation and data being electronic) as a minimum by 2016 (BIS, 2011). Successful implementation of these systems requires an appreciation of how BIM resources (including hardware, software, as well as the technical and management skill of staff) need to evolve in harmony with each other (Succar, et al., 2012).

BIM adoption involves a discussion of the levels which reflect the progress towards a fully collaborative process being achieved. Level 2 BIM is a managed 3D environment created from models/information produced separately by members of the project team and managed by a BIM Coordinator (also known as the BIM Information Manager), who is the central control point for the 3D environment which stores shared data and information. There is therefore a series of domain specific models. The BIM Co-ordinator builds a 3D model from the separate 3D inputs from the design teams and makes sure that each piece of data is inserted from the same origin. The BIM Co-ordinator also ensures that drawing and layer conventions are maintained in order to validate the individual inputs and they will then lead the clash detection and design reviews of the 3D combined model.

The Government has set a target of 2016 for all major Government projects to get to Level 2 BIM – this only affects public sector projects.

Level 3 BIM maximizes the potential of BIM. All the data is stored on a single integrated Project Information Model (PIM) system which can be accessed by all members of the project team to create a completely open design process. Each contributor adds its own specific information to the model on an ongoing basis and tracks any changes made. The model can be used to take account of changes and determine impact on time and cost of the programme can

be used to plan procurement of materials. There is only one model. Designers go in and develop the scheme from a single source. It is frozen at periodic (pre-agreed) intervals so that iterative design progress can be recorded.

Since the Government publication of a BIM Protocol (BIM Task Group, 2013) for use at Level 2, designed to accompany standard forms of contract, the industry has (in theory) the tools it needs to deliver the government's ambitions. The survey shows that 68% of the industry believes that BIM is all about real time collaboration (NBS, 2013), and forty per cent felt that when they use BIM, they need to do so within a collaborative project suggesting that a significant number of people feel that if the project is not collaborative, then it is not BIM (NBS, 2013).

It has been claimed that BIM delivers project cost reductions, reduced build time, reduced claims and less project change costs (Bryde D, 2013). In his recent Construction Industry Council report 'Growth through BIM', Richard Saxon CBE made some important observations about the relationship between BIM, partnering and collaborative forms of contract. He suggested that *"What partnering needed to succeed was BIM"* (Saxon, 2013).

### **3. METHODOLOGY**

The collaborative and participative placements were run over an average of a six month period involving a minimum of ten contact points between the consultant and the organisations. Twelve placements were undertaken. The organisations were a mixture of large clients, architects and first and second tier contractors. As such, this represents a representative cross-sample of BIM stakeholders notwithstanding the small sample size. The views expressed by these respondents are therefore capable of generalisability within the limitations of the research. The limitations were the limited time and resources in which to conduct the study alongside the wider objectives of the placements. Interviews were used to seek the views and interpretations of practitioners (Bourg, 1989). Individuals tasked with introducing BIM into the firms were interviewed and their views recorded. The individuals approached were concerned with delivering change to their organisations in the form of the BIM execution plan. The views and experiences of these opinion formers were therefore extremely relevant to the discussion around BIM adoption.

The research interviews on which the dataset collected is based were conducted after the completion of the placement within four months of the exercise.

This paper adopts a post-positivism philosophy which aims to mirror scientific method whilst remaining realistic to the data in context. An interdisciplinary methodology is introduced given its references to external factors and context. The epistemological nature of the research is that of external enquiry examining a social entity. Interdisciplinary research broadens discourse in terms of its theoretical and conceptual framework which guides the direction of the studies and its specific research methodologies are able to generate empirical evidence to answer research questions (McConville, 2007).

## 4. MAIN FINDINGS AND DISCUSSION

The findings are presented in three sections which deal with the definitions, positive elements and uncertainties detectable within the interview transcripts. Taking these in turn:

### Definitions

The respondents were asked to give their definition of BIM. The following views were recorded and have been grouped together by membership of either the client side respondents or supply side. The emphasis placed by the respondents on the BIM feature they identified reflects their place in the construction process. Essentially, the clients accentuating the importance of the data flow whilst the supply side is more concerned with the key deliverables. The definitions identifying the importance of data were as follows:

*BIM is a process; a new method of storing and transmitting information in a digital format. (Type: Client, Occupier, User, and Facility Management)*

*BIM is assembling supplier information in a 3D model with intelligent information behind which generates schedules, graphical information and a collaborative network of bringing those all together through a common data environment. (Type: Client)*

*I see BIM as an expansion of graphical data to include more informative data around other data as part of a wider building data base. (Type: Client, Operator, Facility Management)*

*BIM being the graphical and information and data representation of a physical building or yet to be built building. (Type: Client, Occupier, User, and Facility Management)*

*The model is built up of intelligent elements used for CAPEX and OPEX (Type: Client, Occupier, User, and Facility Management)*

The clients have a global view on BIM and the legacy of the data involved the process. The last comment shows the financial importance of the information and how it can lead to the savings promoted by the government.

Other definitions identified the importance of collaborative behavior. These respondents were from the supply side as Tier 1 and Tier 2 respondents. Their perspective and viewpoints were more concerned with collaboration and improvement in their working processes. The opportunity to work in a smarter way is a major attraction for these participants. The need and the desire for collaborative practice is writ large here.

*I see it as a sort of very social and behavioural [tool] aligning interests of various stakeholders, operator, maintainer, end user. (Type: Contractor)*

*BIM is the bringing together of different design teams to collaborate on a project bringing about a cost effective well engineered project (Type: Sub-Contractor)*

It is notable that stakeholders in BIM find a definition of the benefits which work best for them and resonate with that person's perception. It is therefore a healthy outcome that the different aspects of BIM at level 2 are stressed and different parts of its appeal are highlighted by the individuals targeted. SMES are therefore all about the collaboration but also need to be aware of the other elements in the definition to access the whole range of BIM benefits.

## **Positive Elements**

The respondents were asked to identify positives in relation to BIM. The client and supply side can be differentiated by the focus of their comments:

*The main benefit for us is the reduction in capital investment (gov't target 20%) and reduction in the number of conflicts if instructed properly (Type: Client, Occupier, User, and Facility Management)*

*What's in it for the client? 20% saving cost certainty and you can sleep at night the builders on time on budget to quality. What's in it for the user? He gets a BIM model and can integrate the model into FM BMS (Type: Client, Occupier, User, and Facility Management)*

These two comments re-iterate the importance of the end game for the client and the translation of data management into financial savings.

The supply side focus is on the key deliverables in term of benefits to the Contractor.

*BIM is trying to keep the information that the client eventually has on his building as something useful rather than gathering dust on a shelf in multiple folders. (Type: Sub-Contractor)*

*The idea of begin able to feed into something, a system that's going to persist that will carry our information on to an entity and having that pass through into the management of the asset is right up our street. (Type: Sub-Contractor)*

*What we rarely see are other professionals interested in what we do. (Type: Sub-Contractor)*

The respondents are imagining BIM for themselves and see the benefits of terms of improvement to working process and offering a better service to their clients. The massive potential to work collaboratively and end a silo-based approach is evident. The vision is clearly to have a means of transcending adversarialism and a desire for a more straightforward and manageable process where supply side views are respected and sought.

## **Comments demonstrating uncertainty**

The comments point at change and flux in the guidance as it has been disseminated from the government. The feelings of being overwhelmed and uncertain are evident from the comments.

*The information on BIM out in the real world is really quite daunting for us (Type: Sub-Contractor)*

*It is still a moving goalpost but we are improving (Type: Sub-Contractor)*

*We all end up following people who we think they know what they're doing and they might not (Type: Sub-Contractor)*

*There are a lot of companies who know a little and everybody seems to be saying yeah we do BIM level 2 and then keeping their head down and hoping they do not get caught out. (Type: Sub-Contractor)*

These comments are indicative of current exposure to BIM processes which are still in their infancy. All of these comments are from the supply side which shows that they are concerned with the deliverable aspects of BIM. This might be explained by the focus to date by the PAS 1192, 1193 and 1195 documentation suite, which approached adoption from the construction process side rather than putting the emphasis on client articulation of their BIM brief through the BIM execution plan. The wisdom of preparing the ground with the supply side makes sense in terms of creating a receptive environment capable of offering BIM services to the eventual users. The downside of this approach is that it is only relatively late in the adoption process that the clients can actually express their needs. Once the process is established the clients will be able to state their needs more clearly. There is uncertainty amongst the supply side insofar as this eventual pronouncement differs from the predicted use.

There is additional reservation as to procurement process with the future UK government BIM Level 3 aspirations in the publication of Digital Built Britain – Level 3 Building Information Modelling Strategic Plan

## **5. CONCLUSION**

It is evident from this study that BIM is viewed positively by both client and supply side in terms of being a welcome development for the built environment. There is clear divergence between the two groups in the views as to how BIM should be defined and the different benefits it delivers. Ultimately, this is not thought to be an issue. The multi-faceted nature of BIM means that there are many different aspects on which respondents may focus. All of the BIM potential benefits are equally valid and provide long term improvement and progress on from existing practices. The scope and encouragement BIM delivers to practices wishing to make a difference regardless of their position is a tangible result of this research. The perception of the respondents pointed to their excitement that they are right now at the forefront of the market and have competitive advantage and an energized workforce as a result.

The views of the client and contractor side are congruent in that they are complimentary and mutually supportive. The emergence of BIM as a genuine panacea for the ills of the industry is therefore appreciable.

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# BIM for Parametric Stadia Design: Do Designers Really Need Visual Programming?

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## Abstract

This research seeks to address complex issues related to stadia design, with a particular focus on parametric terrace modelling. Using advanced Building Information Modelling (BIM) processes and techniques, a dynamic 3D model is developed which automates c-value and capacity calculations, improving efficiency and quality within design firms. The scope of this research has been confined to the activity area, terrace, seating, barriers and gangways. These design areas, particularly terraces, provide constant headaches for designers due to strict regulations. Simplifying this process enables designers to spend more time designing and less time modelling based on meticulous calculations. All aspects of this research have been developed directly within native BIM software to determine if designers really need visual programming to facilitate parametric stadia design. A mixed method approach has been adopted, using quantitative analysis for capturing design formulas and associated parameters, and qualitative discussion addressing problematic and successful aspects of parametric design. It soon became apparent that one parametric family would not be capable of providing designers with the flexibility to meet the significant number of variables associated with stadia design. As such, several families were created using different templates and tools, then federated using a four level nesting methodology. Other findings highlighted that shared parameters are essential to automate data flow to schedules, whilst the incorporation of 3D seats within the terrace family dramatically slows design iterations. That being said, a 20,000 capacity stadium with seats was created in under an hour using the parametric stadia models developed during this research. Conclusions drawn from this research show that complex parametric stadia design can be achieved without the need for third party visual programming software. The process is by no means straightforward and an in depth knowledge of parameters and formulas is paramount for its success.

**Keywords:** BIM, parametric, modelling, design, stadia

## 1. Introduction

Sporting events have attracted crowds in excess of 50,000 since the Colosseum was constructed in the first century AD. Even then there was a basic understanding of crowd safety with the inclusion of 80 entrances/exits (Elliott & Smith, 1993). Stadia design is still a particularly important and complex aspect within the modern day sports and leisure sector. Regulatory bodies have been setting strict design requirements to ensure spectators have a comfortable and most importantly, a safe experience when visiting sporting venues, especially in light of disasters such

as Hillsborough, Ohene Djan and the Kathmandu Stadium, to name a few. These disasters, along with many others have claimed the lives of between 1280 and 1645 innocent spectators, with the number of injuries reaching 10,000. Most of these disasters are a direct result of ‘complex space’, poorly designed spaces which fail to cater for ever increasing crowd sizes (Hoskin, 2004).

As such, designers around the global are trying to eliminate spectator incidents by striving to meet stringent design requirements. The most common method is the use of complex mathematical equations which are performed manually. This is not only inefficient, but promotes costly errors and increases the risk of incidents. Design data such as the stadium holding capacity, appropriate density, c-values, terrace rake, seating info, etc, are being manually entered into schedules and resulting values fed in to drawing packages. This fragmented approach presents endless complications as the design changes, especially on large scale, multiple tiered stadiums. Whilst an inherent problem in stadia design, it presents opportunities within the industry to automate design and information processes through parametric modelling, enabling informed decisions to be made based on accurate geometry and associated data, during design and construction, through to facilities management. These benefits can be realised through Building Information Modelling (BIM).

The importance of parametric modelling within the Architecture, Engineering and Construction (AEC) industry has gained momentum with companies striving to increase productivity, improve quality and create added value. Parametric modelling can be described as creating flexible design and information parameters that can be dynamically altered within a project to quickly adjust 3D geometry and associated information which is automatically mapped to schedules. The advantage of using parametric BIM software is that changes in parameters are generated within minutes to deliver complete and accurate models for use by all disciplines, making it possible to adjust the design until the very last minute (Hubers, 2010). However, this process demands a forward thinking attitude when setting up a project as there are a significant number of design variables to be contemplated, one design element cannot be considered in isolation.

The emergence of visual programming is growing at a steady rate. Visual programming is a graphical algorithm editor which bridges the gap between Application Program Interface (API) and standard software tools and techniques. Free open source software such as Dynamo present designers with the opportunity to use custom nodes, systems and interoperability workflows, which aren’t available in native BIM software packages. The problem lies in the complexity of the program. Users need to have a firm understanding of parameters, formulas and node based design to achieve the desired outcome.

## **2. Research Methodology**

Following a few intense years specialising in the development of parametric BIM models based on manufactures products and specifications, a new challenge was sought. It was during this time where it became apparent that these specialist skills could have a far greater impact if the same principles were applied to the design of complex buildings, rather than the fixtures and fittings

which adorn them. Now working as a BIM Coordinator in a company specialising in stadia design, the problems faced by the industry and the potential solution soon became clear.

This research uses ‘Pragmatism’ knowledge claim position, seeking to address complex challenges relating to stadia terrace design to increase real-world practice orientated efficiency and improve quality. The scope is confined to five key design elements; activity area, terrace, gangways, barriers and automated scheduling. The key challenge will be achieving the desired outcomes whilst restricted to using ‘Out-of-the-Box’ BIM software. The idea being that if flexible stadia design can be achieved without the need for additional and complex visual programming software, it opens the door for widespread application. The design software selection for this research is Autodesk Revit Architecture, but other relative BIM compliant software have similar tools and techniques which can achieve comparable results.

A literature review of previous stadia related studies along with industry design standards is made to form a solid foundation on which to develop a parametric stadia component that can be utilised during conceptual design through to detailed design and construction phase. Pragmatism is not committed to any one system of philosophy and reality (Creswell, 2003). This research approach facilitates the best outcomes through a mixed method technique which is ideally suited to a practical, parameter based study. Inquiries are drawn liberally from quantitative analysis for capturing design formulas and associated parameters, and qualitative discussion addressing problematic and successful aspects of parametric design within a native Revit environment.

### 3. Literature Review

Firstly, when studying stadia design it is important to get a complete overview of the many standards and guidelines which dictate how architects design stadiums to provide a comfortable and safe environment for spectators. The documents highlighted in Table 1 provide an invaluable source of information to help shape the methodology from which a parametric stadia model, applicable within the United Kingdom (UK) and internationally, can be developed. DCMS, 2008 provide a zonal planning diagram which divides stadia design into 5 key zones; 1 - activity area, 2 - viewing accommodation, 3 – internal concourse, 4 – outer circulation area, and 5 – outside sports ground. This research focuses on zones 1 and 2, designing from the central zone outwards.

*Table 1: Important Stadia Design Literature*

<i>Code</i>	<i>Document Title</i>	<i>Issuer, Year</i>	<i>Doc. Type</i>	<i>Application</i>
01	<i>FA National Ground Grading A-H</i>	<i>FA, 2011</i>	<i>Standard</i>	<i>United Kingdom</i>
02	<i>FA National Ground Grading Step 1-7</i>	<i>FA, 2015</i>	<i>Standard</i>	<i>United Kingdom</i>
03	<i>UEFA Stadium Infrastructure Regulations: Edition 2006</i>	<i>UEFA, 2006</i>	<i>Standard</i>	<i>International</i>
04	<i>Accessible Stadia</i>	<i>FSIF &amp; FLA, 2003</i>	<i>Guide</i>	<i>United Kingdom</i>
05	<i>BS EN 13200 Spectator facilities – Part 3: Separating elements - Requirements</i>	<i>BS EN, 2005</i>	<i>Standard</i>	<i>International</i>
06	<i>FSIF Data Sheet 5: Services and Support Facilities</i>	<i>FSIF, 2004</i>	<i>Guide</i>	<i>United Kingdom</i>

07	<i>Guidance on designing for crowds – an integrated approach</i>	CIRIA, 2008	Guide	United Kingdom
08	<i>Pavilions and Clubhouses</i>	Sport England, 1999	Guide	United Kingdom
09	<i>Sports Halls: Sizes and Layouts</i>	Sport England, 2000	Guide	United Kingdom
10	<i>Stadia: A design and development guide – Fourth Edition</i>	Geraint, Sheard & Vickery, 2007	Guide	International
11	<i>Guide to Safety at Sports Grounds – Fifth Edition</i>	DCMS, 2008	Guide	International

There have been previous studies into parametric stadia design such as Hudson, et al., 2011 who documented the parametric design of the Aviva Stadium with a focus on its form and façade detailing; Miller, 2009 study covering all angles of stadia design using a multitude of software programmes; and BIM Troublemaker, 2010 who spent 13 months developing a native revit parametric stadia model. There is however one commonality between all studies, they each fail to provide a useful insight into how their models have been created from a technical perspective. Shared knowledge is an essential factor in helping the industry to innovate and something which this paper seeks to address.

### 3.1 Activity Area

*Firstly, it's important to start design in the central zone (Zone 1 – Activity Area) and work outwards towards the terrace and concourse areas. The activity areas were created using the 'Generic Model' family but could also have been developed using the 'Generic Model Adaptive' family category. It was important to create each activity area as an individual family, but using the same Shared Parameters for the pitch length, depth, perimeter offset, material, etc (see*

Figure 1). The reason for this is that when the individual activity area families are nested into the master activity area family the parameters remain consistent when mapped.

The main aspect that designers require is flexibility. This needs to be considered and built into the activity area family so that the model is applicable to a wide variety of sports. Another key consideration is the visibility settings for each activity area family. This should be tackled directly within the master activity area family so that each activity area (football, tennis, cricket, etc) can be turned off as necessary. Once all families were nested into the master activity area family, parameters mapped and new visibility parameters created, the master family was loaded and placed within a new or existing project.

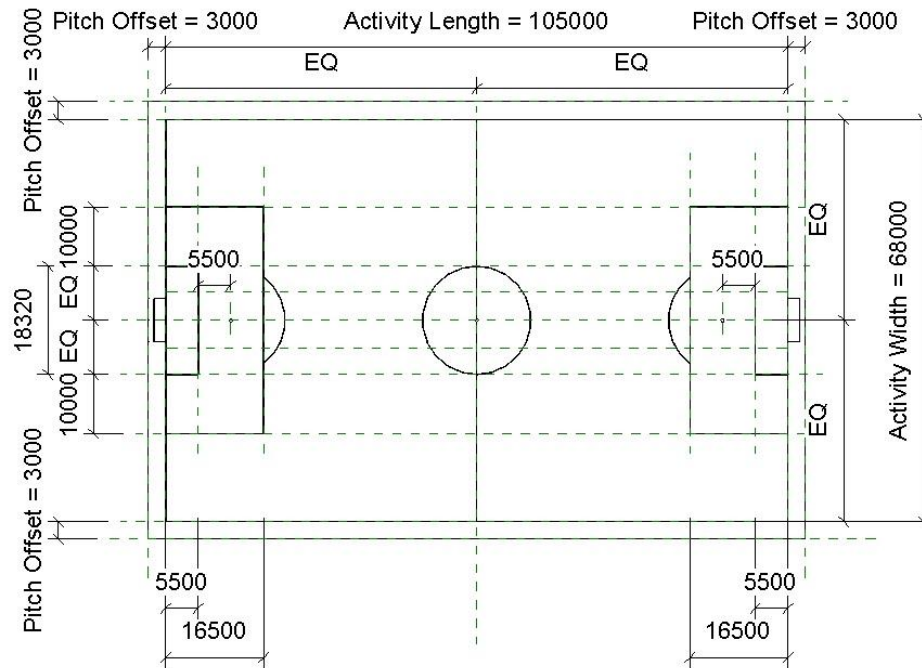


Figure 1: Activity Area Parametric Layout

### 3.2 Terrace

Terrace design is the most complex challenge when designing any new stadium. There are substantial variables which need to be considered. As such, it cannot be a 'one family fits all' process as this would severely limit the flexibility of the model for the end user. A better approach is to identify the key areas and design flexible models for each, which can then be used in conjunction with each other to perform complex design proposals. Aspects of terrace design which need to change dynamically include terrace riser height, depth, thickness, length, material, etc. Not only that, specific formulas need to be embedded which reference parametric values in order to extract c-value and capacity statistics on the fly (see Figure 2).

The complexity of creating a parametric terrace model provokes the need for a four-layer nesting system which covers all eventualities. The process starts with the creation of a single terrace sweep as a 'Generic Model' family with built in parameters. The terrace riser needs to have an offset which is linked to the terrace thickness parameter so that once arrayed, the row behind sits nicely on top with the correct terrace height and the join line disguised by the terrace seats in front.

This family was then nested into a separate 'Generic Model' family to create the terrace array which needed to be aligned and locked to specific reference planes. Parameters were mapped to enable the model to function based on input values. This nesting process simplifies the development and application of parametric design, and in some cases parametric design would not be possible without it. Once the terrace had been arrayed, an additional parameter needed to be added which allows the end user to specify the desired number of rows. The problem faced here is that an arrayed integer parameter doesn't allow an input value of '1'. To bypass this an additional parameter and formula was developed to show a single terrace family and hide the arrayed terrace if the user entered a number  $<2$ . It was also important to lock the second arrayed terrace to the top and rear of the first terrace row. Failing to do this causes the arrayed terrace rows to malfunction once the terrace height, depth or thickness parameter is adjusted.

This family was then nested into a new 'Generic Model Adaptive' family where the process of mapping parameters was repeated prior to setting the formulas to generate c-value and capacity data. Once mapped, an adaptive node was placed which will act as the insertion point when the family is loaded into the project. This node was aligned and locked to the activity area touchline so that c-value data is generated. A model line was then drawn in the family spanning from the first row to the rear row with a divided path linked to the number of rows parameter. A lined can then be placed from the adaptive node to the first node of the divided line and arrayed to create the spectator sightlines using the 'Repeating Detail' command. Parameters also needed to be formed for the horizontal distance of the first row from the touchline and the vertical offset of the first row from the touchline. Additional 'Reporting Parameters' were created for 'R-Vertical height of sightline from the Point of Focus (POF)' and 'D-Horizontal distance of sightline from the POF' which could be referenced when calculating the c-value. These measurements needed to be taken from the rear terrace spectator to represent the minimum c-value achieved by each terrace. The capacity was then calculated by creating a formula based on the Terrace Length\*No. Rows/Seat Width. To take this calculation one step further, a desired terrace length parameter was added which drives the actual terrace length parameter, rounding the length up to the nearest seat width. This formula enables the capacity to be viewed and scheduled without the need for memory intensive 3D seating. However, the idea is to have a basic terrace family with no seating to be used during iterative design and easily swapped out for a more detailed family during document production and visualisation.

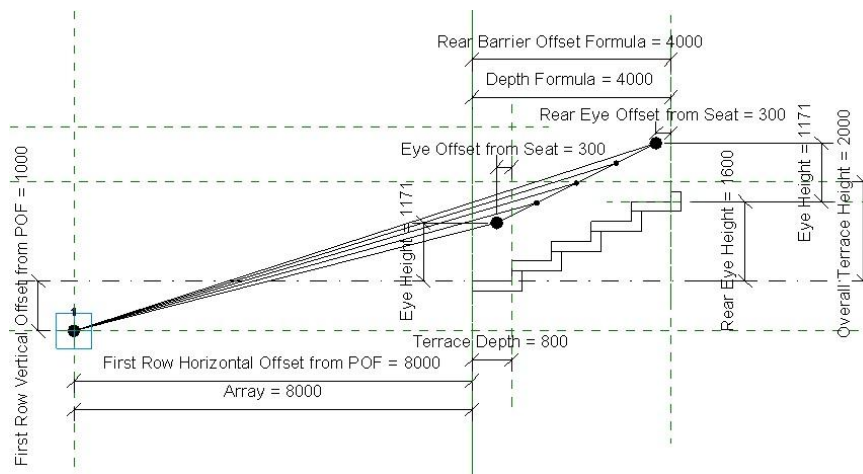




Figure 2: Master Basic C-Value Parametric Layout

### 3.3 Barriers and Gangways

Lateral gangways tend to be formed in front of the front row and behind the rear terrace row so it makes sense to build these in as a design option. In doing so it is important to create these as an option which can be turned on and off as required using visibility parameters.

The barrier design commenced as a 'Generic Model' family with built in parameters to control its thickness, length and material. This family was then nested and mapped to a separate 'Generic Model' family for the front gangway extension whose length and material parameters correspond to the shared parameters used in the terrace families. An additional parameter was then added to adjust the gangway depth. This model is then nested and mapped to the c-value family where it is aligned and locked to the front row terrace (see Figure 3). Depending on which side of the reference planes the family is created on will impact upon which way it flexes once the depth value is adjusted, so it's important to get this correct or the alignment will break and the parameters fail.

This family can also be used for the rear gangway, however the gangway family needs to be situated on the opposite side of the reference plane so that the gangway depth increases from the barrier outwards. This family is aligned and locked to the rear terrace riser. Separate visibility parameters need applying to the front and rear barrier/gangway families so they can be turned on and off individually. Because of the '1' integer array issue, an 'if statement' formula needed applying to the rear barrier/gangway family to turn it off if the No. Rows < 2. This means a separate barrier and terrace infill family needed placing at the rear of the first row with the reverse 'if statement', not (No. Rows > 1).

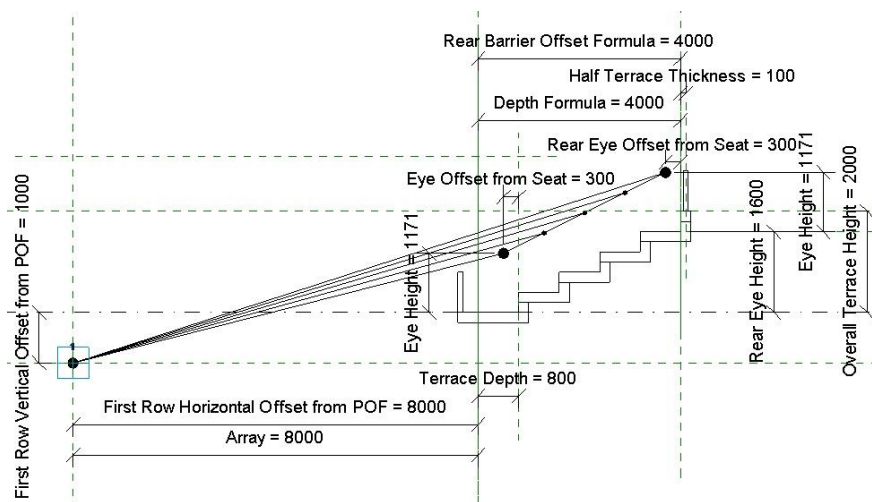


Figure 3: Master Basic C-Value Parametric Layout Incorporating Barriers and Gangways

### 3.4 Seating

Again, similar to the terrace family process, a new ‘Generic Model’ family was created to model the individual stadia seat. The Level of Development (LOD) can vary dependent on the end users requirements, but in this instance, parameters have been created for seating height, seat height, seat depth, seat width, armrest height, armrest length, armrest thickness, clearance, etc. Other visibility and material parameters were applied to the armrest and seat.

Once satisfied with the individual seat family, this needed to be nested into a copy of the single terrace family, parameters mapped and arrayed along the length of the terrace. The array required a parameter for the number of seats which is driven by a ‘Terrace Length/Seat Width’ formula. When the model has been flexed to determine if the parameters function correctly, the family was nested into a copy of the arrayed terrace and the existing family swapped out for the new seating terrace. During this process some of the parameters break and need to be re-applied. Once all the parameters have been mapped, the seats fill the terrace and adapt to changes in terrace length and number of rows.

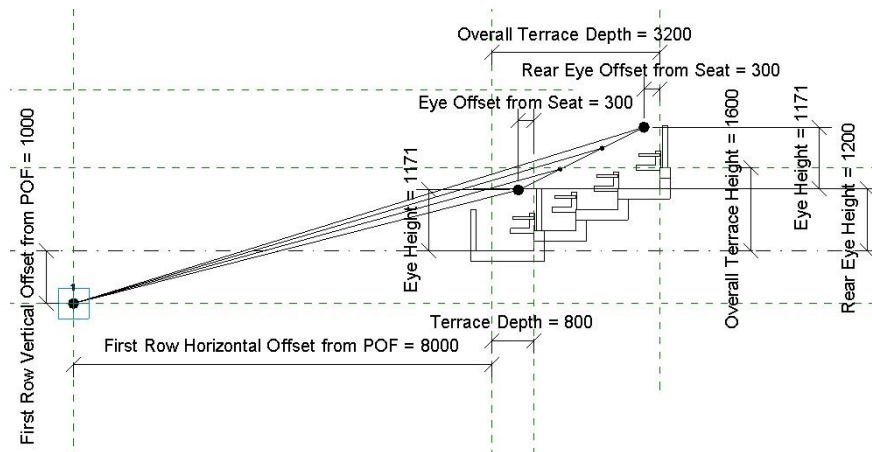


Figure 4: Master C-Value Parametric Layout Incorporating Barriers, Gangways and Seats

This family can then be nested and mapped into a copy of the c-value adaptive terrace family, again resolving any broken parameters affected during the process (see Figure 4). We now have a basic family for quick design iterations and a heavier family incorporating 3D seats for document production and visualisation.

## 4. Parameters

As discussed, there are a substantial number of parameters (55) required to not only make the terrace function correctly, but provided the required flexibility to make it applicable to industry (see Table 2). With this quantity of parameters to manage, it is essential to use ‘Shared Parameters’ to add consistency and to think carefully about the naming and categorising of the parameters. The naming is important as the parameters will be sorted in alphabetical order, so to make things easy to find, the best method is to start the name with all the same identification word e.g. terrace, seat, barrier, etc, followed by a differentiator to group interrelated parameters. The categorisation is equally important to also separate and group parameters within the project. The

method used here is to place the parameters which are dormant/formula driven within a category lower down the alphabetical list to keep them out of the way and prevent unnecessary scrolling.

Table 2: Master C-Value Terrace Family Parameters

Parameter	Value	Formula
<b>Text</b>		
Stand Name (default)		=
Terrace Name (default)		=
Tier (default)		=
<b>Materials and Finishes</b>		
Armrest Material	Armrest Material	=
Barrier Material	<By Category>	=
Seat Material (default)	Seat Material	=
Terrace Material	<By Category>	=
<b>Dimensions</b>		
Barrier Height (default)	800.0	=
Barrier Offset Left (default)	0.0	=
Barrier Offset Right (default)	0.0	=
Barrier Return Length (default)	1000.0	=
Barrier Thickness (default)	100.0	=
C - C Value (default)	152.6	= $D * ((\text{Terrace Height} + R) / (D + \text{Terrace Depth})) - R$
Capacity (default)	40.000000	= $\text{Terrace Length} * \text{No. Rows} / \text{Seat Width}$
D (default)	10100.0	= $\text{First Row Horizontal Offset from POF} + ((\text{No. Rows} - 1) * \text{Terrace Depth}) - \text{Eye Offset}$
Eye Height	1171.0	=
Offset from Seat	300.0	=
Offset from POF (default)	8000.0	=
Offset from POF (default)	1000.0	=
		= $\text{Terrace Length} / \text{Seat Width}$
		= $\text{No. Rows}$
		= $(\text{No. Rows} * \text{Terrace Height}) + \text{Eye Height}$

## 4.1 Scheduling

Shared Parameters were the key to successful automated stadia scheduling as these allowed any parameter created during the development of the stadia families to be mapped to an ‘in-project’ schedule (see Table 3). The columns of data were automatically updated as the stadium was being designed, providing critical, up to date information as the design progressed. These parameters show only a fraction of the information which could be utilised if required. Each independent terrace family has an ‘Instance’ parameter for the ‘Stand Name’, ‘Terrace Name’ and ‘Tier’, that way each and every terrace element could easily be referenced and the schedule filtered depending on the designers’ requirements. In this case the schedule rows have been grouped based on ‘Stand Name’ and the ‘Itemise Every Instance’ turned off, just showing the total capacity per ‘Tier’ of each stand.

Table 3: Automated Zone 2 – Viewing Accommodation Schedule

Zone 2 - Viewing Accommodation											
Terrace	Tier	T - Terrace Depth	N - Terrace Height	Terrace Length	Terrace Thickness	Overall Terrace Depth	Overall Terrace Height	No. Rows	Seat Width	C - C Value	Capacity
Stand A											
A-1	Ground	800	500	30000	200	13600	8500	17	500	84	3,060
A-2	First	800	600	10000	200	8000	6000	10	500	82	1,400
											4,460
Stand B											
B-1	Ground	800	400	20000	200	12800	6400	16	500	81	6,400
B-2	First	800	600	15000	200	9600	7200	12	500	78	2,520
											8,920
Stand C											
C-1	Ground	800	400	10500	200	8800	4400	11	500	149	1,848
C-2	First	800	600	20000	200	9600	7200	12	500	139	2,880
											4,728
Stand D											
D-1	Ground	800	500	10500	200	13600	8500	17	500	84	2,142
D-2	First	800	600	10000	200	9600	7200	12	500	78	1,680
											3,822
Grand total											21,930

## 5. Parametric Stadia Design

### 5.1 Parametric Design Framework

The overall parametric design framework adopted during this research is highlighted in Figure 5. This demonstrates the four layered nesting system and link with the project environment. There are several design areas which needed to be addressed so it was important to separate these into sections, then the sections placed within zones. The complexity of the nesting system is clearly evident, even though this research is confined to just the activity area and viewing accommodation. There are lots more areas and zones which could be incorporated into the framework moving forward so it's essential to have a structured system to creating content. This strategy prevents developers from getting caught up in the labyrinth of complications inherent with multi-layer nesting and provides the basis for a scalable and repeatable approach.

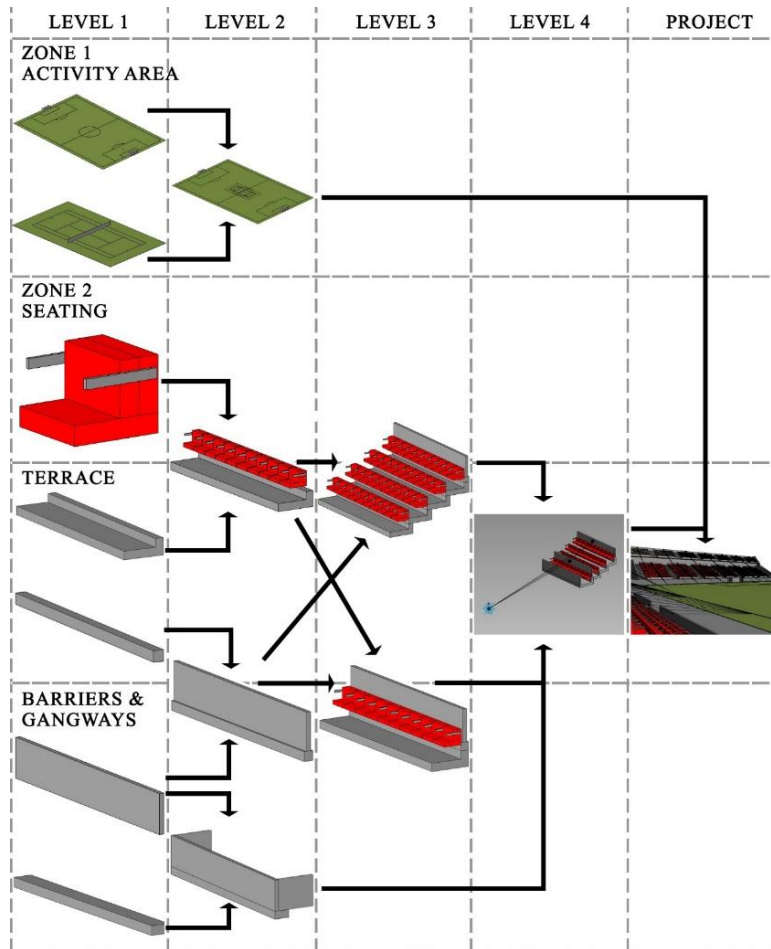


Figure 5: Overall Parametric Design Framework

## 6. Discussion

Autodesk Revit being the design software of choice has over 80 family categories which offers flexibility as they each have their own tools and functionality. However, this can also provoke problematic issue with template selection as this cannot be changed in most cases once design work commences. Only two family categories were used in the parametric development of the stadia model, 'Generic Model' and 'Generic Model Adaptive'. The 'Generic Model' family is great for constructing general objects such as the terrace, seats, gangways and barriers, but the complex c-value calculations could only be realised using the 'Generic Model Adaptive' family for its inherent adaptive tools.

Formulas are a fundamental aspect of parametric modelling, but a developer also needs to understand how formulas are used to drive 3D model parameters and associated data in order for it to function correctly. In many instances the development hit roadblocks which prevented progression via the use of standard parameters. Additional parameters were used as a workaround with attached formulas to bypass these roadblocks. It was also essential to create a 'Shared Parameter' file which is used consistently across all families to improve efficiency and enable the data to automatically populate the stadia schedule. 'Project Parameters' created during family development will not be mapped to the 'in project' stadia schedule.

As anticipated, the c-value calculations proved the most complex challenge due to the sightlines, variables and formulas involved. The c-value adapts dynamically to changes in both horizontal and vertical distance to the POF, terrace height and depth, and eye height and eye offset. The c-value is taken from the rear terrace row which has the worst sightlines which guarantees the minimum c-value per terrace. Ideally this can be taken further so that the end user can input a required c-value which then generates a unique terrace height for each row, forming a parabolic curve and consistent c-values throughout the terrace. It would also be advantageous for the data of each row to automatically populate the schedule. Another serious problem encountered was the inclusion of 3D seats to the terrace family. Whilst this rapidly speeds up the process through automation, it dramatically slowed design iterations with each change in parameter taking approximately 8 seconds to generate. This was mitigated by developing a duplicate terrace family without the seating to be used during design and swapped out for the terrace seating family once finalised. This methodology meant design changes are instant.

The benefits of the parametric model are already being realised with the 3D terrace design, including seating, of a 20,000 capacity stadium being achieved in under one hour. This also included a fully populated schedule of terrace related data. Once created it is a simple case of manually incorporating the concourse areas, stairs and roof structure based on the clients' requirements and site specific constraints to complete the design.

## **7. Future Research**

This research merely scratches the surface of potential issues which could be tackled through parametric design. There are five key areas which would benefit this research and enhance the stadia design process through automation. These areas include:-

1. Automated C-Values Data Per Row – where the designer inputs the desired c-value and this figure is used to drive the terrace height of each row, forming the optimum spectator sightlines through a parabolic curve.
2. Stairs and Railings – derived and constrained by industry regulations and standards.
3. Roof Canopy – which to be used for quick iterations using parametric design options.
4. Structural Support– integrated into the parametric terrace family with parametric options for column and truss design.
5. Concourse Areas – which can be used to form internal and external concourse areas.

## **8. Conclusions**

The primary objective of this research was to determine whether it is possible to develop a parametric stadia family, without the need for visual programming, which could be used by designers to increase efficiency and improve quality. Whilst the answer to the question is yes, the process is by no means straightforward. A high level understanding of complex formulas and parametric modelling techniques is essential to construct a robust functioning model. That being said, the process is more straightforward than a visual programming methodology as this would require an in depth understanding of parameters and formulas, but also nodal design.

Whilst the objective has been met in the broadest sense, the path to arrive there deviated slightly from the original plan. The key reason for this was that upon initial development it quickly became apparent that a single parametric family would severely limit the designers' flexibility due to substantial design variations. There are so many complex factors which needed to be considered such as the terrace, seating, barriers, gangway and activity area, which all have strict requirements and unique variables. Thus, it was essential to develop these key aspects as individual parametric families which can be used and function in unison. This method was found to be the most manageable from a development perspective, yet dynamic and user-friendly for the designer.

The sheer amount of variables involved in stadia design presented endless complications. Limitations include the inability to automate data per terrace row and lack of integration of additional elements such as stairs and railings, roofs, structure, concourses, etc. The process to create a flexible model needed to be rethought over and over again, but the framework is now in place from which a robust parametric stadia model can be further refined. This framework and associated model provides an efficient system which can be used by sports and leisure designers to increase efficiency whilst improving quality.

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# Approaches for Assessing BIM Adoption in Countries: a Comparative Study within Qatar

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## Abstract

The adoption of Building Information Modelling (BIM) is now examined at different scales ranging from organisations, through supply chains, and across whole countries and markets. For the assessment of BIM adoption at country and market scale, two main approaches are being utilised. The first traditional approach utilises a survey of industry stakeholders operating within a defined market/country to assess BIM diffusion. The second emerging approach adopts specialised macro BIM adoption models and metrics. In this paper, we aim to apply and compare these two approaches for investigating BIM adoption within Qatar.

In the implementation of the survey approach, we selected key client, contractor and consultant organisations and conducted 28 face-to-face interviews in an attempt to overcome some of typical limitations that might occur in traditional survey-based approaches (e.g. unknown and biased population). The obtained results included: BIM is increasingly specified by clients on large construction projects; BIM experience has become part of the pre-qualification criteria; traditional Design Bid & Build (DBB) is the predominant procurement route with an increasing use of the Design & Build (DB); lack of national BIM standards or guidelines and adoption of a combination of UK and US standards. Although these results provide a general understanding of the BIM landscape in Qatar, they remain qualitative and not actionable for policy makers, e.g. for developing BIM adoption strategies. Then, we applied two specialised macro BIM adoption



models – i.e. Diffusion Areas model and Macro-Maturity component model developed by Succar and Kassem (2015). This second approach was capable of providing a rating of the different areas of BIM diffusion and a holistic discovery assessment of the country BIM maturity. Using the same approach, the results from Qatar can be benchmarked against those of a target country and can be utilised to inform a Qatari-specific BIM adoption policy. Based on this result, the research concluded that new approaches such as the macro BIM maturity approaches should be increasingly encouraged and used to complement the traditional market BIM surveys.

**Keywords:** BIM, Diffusion Areas, Macro BIM adoption, Macro Maturity Components.

## 1. Introduction

Building Information Modelling is now widely acknowledged as a revolutionary change in the technologies, processes and policies underlying the Design, Construction and Operation (DCO) industry. BIM transformative impact on the DCO industry includes a technological and procedural shift (Succar, 2009; Eastman et al., 2011). It is also considered a disruptive impact forcing the industry to rethink deliverables, roles and relationships (Eastman et al., 2008; Smith and Tardiff, 2009).

Following years of escalating connotation and impact of BIM, industry associations, governmental bodies and academic communities across several countries are increasingly releasing a wide variety of Noteworthy BIM Publications (NBPs) (Kassem et al., 2015). One of the NBP types are the BIM surveys that aim to assess BIM diffusion – defined as the spread of innovation adoption within a given population (Rogers et al., 2005) – within a defined market for a single discipline or across all disciplines. For example, a nationwide survey of architects, engineers, contractors, owners, manufacturers and others (facility managers, software vendors, and project managers) has been conducted in Australia (BEIIC, 2010). Similarly in the UK, the National Building Specification (NBS) conducts annual surveys of Architecture, Engineering and Construction (AEC) professionals (NBS, 2015). In North America, a survey of 582 professional was performed by McGraw-Hill Construction (2012) to assess BIM diffusion rates. These surveys often lack the support of a theoretical framework and may involve an unknown population.

This paper aims to compare the findings from two approaches for assessing market-wide BIM adoption. The first approach is the traditional survey-based approach with enhancement – selection of a known and representative sample and inclusion of all BIM fields namely, process, policy, technology and people (Vukovic et al., 2015; Kassem et al., 2013).

The second approach involves the utilisation of emerging models for assessing macro BIM adoption within a defined market. In recent years, several countries have launched their BIM adoption strategies and national initiatives. Research has responded to this need by developing specialised models that can be used to assess the market wide BIM adoption. One of the earliest studies in this domain is the one proposed by Succar and Kassem (2015). This study has developed five macro BIM adoption models, namely, these are Model A: diffusion areas, Model B: macro-maturity components, Model C: macro-diffusion dynamics; Model D: policy actions, and Model

E: macro-diffusion responsibilities. This research will implement ‘*Model A: Diffusion Areas*’ and ‘*Model B: macro-maturity components*’ and their accompanying metrics to assess BIM adoption in Qatar.

The implementation and results from both approaches, i.e. (a) the survey-based approach and (b) the specialised models for macro BIM adoption, are respectively described in the subsequent two sections.

## **2. Market-wide BIM Adoption: Survey-based Approach**

The interviewees included stakeholders from Client (N=9; 32%), Contractor (N=5; 18%) and Consultant (N=14; 50%) organizations working on several ongoing projects in Qatar. The interviews covered four domains of interest: Policy, People, Process and Technology (Grys and Westhorpe, 2011; Kassem et al., 2014), containing a total of 18 questions/discussion topics with 36 subtopics.

The policy section of the interviews investigated project delivery methods and types of contracts used in Qatar. The people section investigated professional BIM related roles and the challenges around the availability of BIM skills and knowledge and the corresponding learning and training opportunities within the Qatari construction industry. The process section aimed to analyse topics such as the BIM requirements, availability and use of BIM execution plans, standard project phases or plan of work, the adopted Levels of Detail (LoD), and the roles and responsibilities of different stakeholders towards such process related topics. Finally, the technology section aimed to survey the BIM tools used across the project lifecycle in Qatar. The following sections highlight the results in each of the four domains of interest.

### **2.1 Policy**

The common two project delivery methods utilised in Qatar are Design and Build (68%)<sup>1</sup> and the Design-Bid-Build (75%). The predominantly used contract types are FIDIC (International Federation of Consulting Engineers) contracts (68%) and American Institute of Architects (AIA) contracts (18%). Other contracts included the New Engineering Contract (NEC) (4%), Public Works Authority contracts (7%) and professional service agreements with consultants.

BIM standards are required on the majority of projects (68%) and 75% of interviewees think that BIM should be enforced on projects. The BS 1192: 2007 is the most widely used standard on projects in Qatar (61%) followed by the PAS 1192-2: 2013 (39%). Other BIM related standards identified with a lower frequency include: AEC (UK) CAD standards (AEC, 2012), AIA Integrated project delivery BIM protocol exhibit (AIA, 2008), National BIM standard (NIBS, 2012), Singapore BIM guide (BCA, 2012), BIM project execution planning by Penn State University (PSU, 2010), and the Global Sustainability Assessment System (GORD, 2014). The

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<sup>1</sup> Values in brackets refer to the percentage of respondents.

majority of respondents (89%) believed that the government should be developing the required BIM standards for the industry with the participation of educational institutions and private organisations.

## 2.2 People

The BIM related roles identified within the Qatar construction industry according to the interviewees are summarised in Figure 1. Under ‘other’, roles including BIM project managers and BIM interface managers were mentioned by 30% of respondents. As to the sourcing and skilling up of individuals playing these BIM roles, 75% mentioned in-house training complemented with the hiring of external BIM construction in 36% of cases. The majority of respondents (96%) complained about the lack of BIM skilled professionals in their supply chains and highlighted the need for training. At the same time, 46% of respondents reported challenges facing their organisations in the development of BIM professionals – i.e. difficulty in convincing people to enrol on training courses and the availability of appropriate BIM training and learning opportunities.

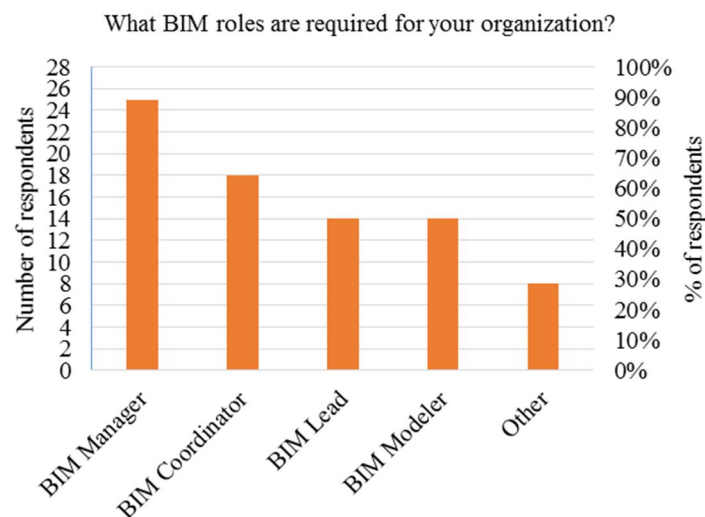


Figure 1: BIM-specific roles in Qatar

## 2.3 Process

There was a unanimous agreement among all interviewees (28) that BIM is used on projects in Qatar when it is required by clients and 70% of respondents highlighted the increasing inclusion of BIM related assessment in the tender prequalification and selection process. The prevalent use of BIM, according to 75% of respondents, is the federated BIM in common data environment. The most frequently required (indicated by 64% of respondents) Level of Development (LOD) is the LOD 300. Other LOD required are LOD 100 (7%), LOD200 (18%), LOD 400 (32%) and LOD 500 (11%).

Several types and labels for the BIM documents used on project to help manage the process were identified: BIM execution plan (68%), BIM implementation plan (46%), BIM strategy (39%),

modelling guidelines (36%) and ‘other’ documents – i.e. BIM manual, owner’s guide and CAD manual - (7%). The responsibility for defining the LOD is attributed to the client (71%), the designer (29%) or the contractor (7%).

A wide variety of project stages or plan of works is adopted in Qatar including the RIBA Plan of Work (29%) and the AIA five phase of design (14%), the CIC Scope of Services and the PMI project management processes (7%). ‘Other’ plan of works such the BSRIA Design Framework for Building Services and client specific project phases was reported by 46% of respondents. As a consequence of these multiple project stages, interviewees reported issues such as the misinterpretation and the lack of adherence to project stages. They concurred about the need for developing standard project stages and BIM process maps for Qatar’s construction industry and the joint responsibilities of government bodies, educational institutions and the private sector in this task.

## **2.4 Technology**

This part of the interview aimed to identify the technologies used across all phases of the project lifecycle in Qatar. A summary of the result is depicted in Figure 1. It is clear from Figure 1 that for each of the four project purposes, there is a technology that is predominantly used. This exercise was intended to inform the development of lifecycle BIM information flow which is one of the overarching goals of the funded research project. Hence, in addition to identifying the technologies used on projects, this interview part aimed to capture information about the used file exchange formats. Predominantly used exchange formats include: IFC (68%), 3D PDF (25%), COBie (21%), NWC/NWD (50%) and ‘other’ proprietary file formats (57%).

## **3. Market-wide BIM Adoption: Specialised Models**

Six experts and practitioners operating in Qatar were invited to apply the two models (i.e. Model A and Model B). The experts were selected using the snowball sampling procedure. The snowball sampling procedure occurs when the researcher accesses participants through contact information that is provided by other participants (Noy, 2008). The initial subjects serve as ‘seeds’ through which wave 1 subjects are recruited; wave 1 subjects in turn recruit wave 2 subjects, etc. (Heckathorn, 2015). The snowball effect enabled the implementation of a non-probabilistic sampling approach. This enabled the research to start with an exploratory sample – not a representative one – that could lead to generalizable results through either (a) cumulative approach (further identification and participation of experts until data saturation, convergence or statistical validity is achieved) or (b) Delphi technique to achieve consensus about the results. In this case, the generalisation was achieved using a mini Delphi approach (a single round) where the mean, excluding the most deviating ratings from it, was circulated to all experts to achieve consensus about the measurement. The two models and the results from their applications within Qatar are described and analysed in the subsequent two sections.

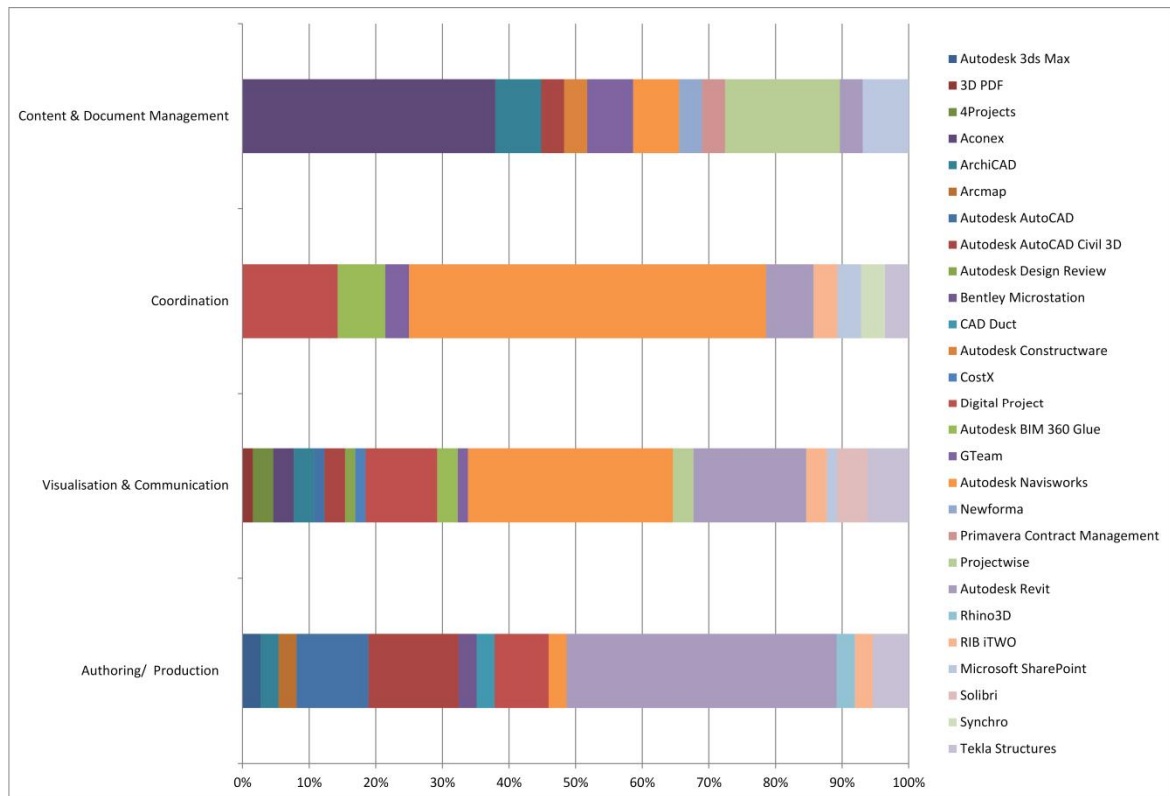
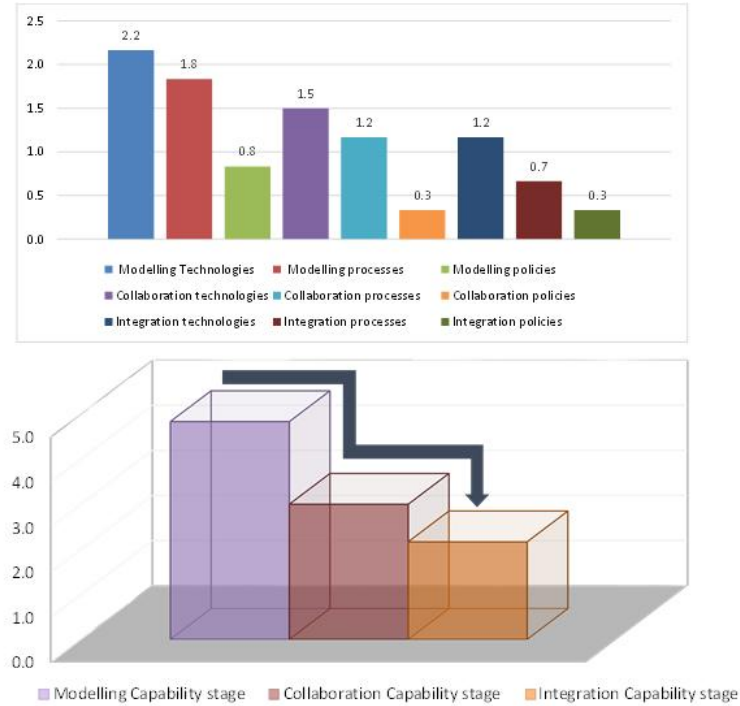


Figure 2: Technologies used on construction projects in Qatar

### 3.1 Assessing the Areas of Diffusion in Qatar

The Diffusion Areas model establishes nine areas for targeted BIM diffusion analysis and planning which can be assessed independently or collectively. These nine areas of diffusion are the result of overlaying the three BIM field types (technology, process and policy) and three BIM capability stages (modelling, collaboration and integration). This model can be used to assess the extent of BIM diffusion within organisations and across markets. The six experts were asked to rate the level of each BIM diffusion area according to a five-level scale: [0] low; [1] medium-low; [2] medium; [3] medium-high; and [4] high.

Figure 3 (upper part) displays the mean for the levels of diffusion of the nine areas. The results show that all areas of diffusions, with the exception of modelling technologies, are rated below medium. This is a reasonable outcome as modelling technologies are considered one of the capability sets (software step) required to move into the first BIM capability stage – i.e. modelling stage (Succar, 2009). This result is complemented with the results obtained from the survey-based approach (Figure 2) where the spread of modelling technologies was found to be prevalent in Qatar's construction industry. This result can be better understood in the lower part of Figure 4, which aggregates the score of the three fields (i.e. policy, process, technology) for each capability stage. It shows that the highest concentration of BIM diffusion rates is in low-level modelling capabilities followed respectively by lower mid-level collaboration capabilities and high-level integration capabilities.



*Figure 3: Assessment of BIM Diffusion Areas in Qatar*

The levels of diffusion of three areas of policy (i.e. modelling policies, collaboration policies, and integration policies) are all rated below medium-low. The integration policy area has the lowest diffusion. This area refers to e.g. the rate of adoption of integrated supply-chain standards, protocols and contractual agreements; rate of proliferation of interdisciplinary educational programmes. Analysing the level of diffusion obtained for this area in conjunction with the survey results for the policy domain (Section 2.1), the result can be considered reasonable and complementary. Indeed, the survey showed the lack of Qatari specific collaboration protocols and the simultaneous coexistence of several standards and protocols within Qatar leading to misapprehension among organisations of the supply chain. Similarly, the results for the three process related areas of diffusions (i.e. modelling processes, collaboration processes and integration processes) are complementary and congruent between the survey and the Diffusion Area model.

There are key differences between the two approaches. Despite the adequate design and structuring of the survey into topics (i.e. people, process, policy and technology), the survey results can be used only for a general understanding or a situational analysis of a market. Indeed, they do not differentiate or recognise the different BIM capabilities that coexist within a market as demonstrated by the Diffusion Areas model and consequently, they are unable to provide a corresponding assessment of such areas. Moreover, the results from the survey are not actionable by policy makers interested in targeting a specific BIM diffusion area (e.g. achieve a high diffusion level in collaborative technologies). The Diffusion Areas model provides such capabilities through the generation of targeted ratings for comparative market analysis.

### 3.2 Assessing the Macro-BIM Maturity of Qatar

The second model (Model B: Macro-maturity components) identifies eight components that must be measured and compared in order to establish the BIM maturity of a market (Figure 4). These eight components are: 1. Objectives, stages and milestones, 2. Champions and drivers, 3. Regulatory framework, 4. Noteworthy publications, 5. Learning and education, 6. Measurements and benchmarks, 7. Standardised parts and deliverables, and 8. Technology infrastructure. These components are assessed using the BIM Maturity Index (BIMMI) which includes five maturity levels: [a] Ad-hoc or low maturity (0); [b] Defined or medium-low maturity (1); [c] Managed or medium maturity (2); [d] Integrated or medium-high maturity (3); and [e] Optimised or high maturity (5) (Succar, 2010). The assessment can be made holistically (low detail discovery assessment) or granularly (higher detail evaluation assessment). The discovery assessment is beneficial for comparing the relative maturity for each macro-component against the other seven components; while ‘evaluation’ assessment enable the detailed analysis of each component using specialised metrics applicable to that component only (Succar and Kassem, 2015).

Figure 6 reports the assessment result for the eight components. The maturity of all macro components in Qatar, with the exception of the ‘technology infrastructure’, falls within the interval ‘low’ and ‘medium-low’. ‘Learning and Education’ and ‘Measurements and Benchmarks’ have the lowest maturity rating. While the survey did not provide distinct components and metrics for their assessment, some of its qualitative results (e.g. limited training and learning opportunities, lack of country specific standards and protocols) support the assessment conducted using the macro maturity component. From the comparison of the application and results from both approaches (i.e. survey based and Macro-Maturity Components model), key advantages that can be attributed to the macro maturity model are: (a) it identifies and measures eight distinct but complementary components underpinning the BIM maturity of a market; (b) Improvement targets, in terms of maturity level, can be set for each of the eight components, and (c) Can promote learning in policy development and implementation for each of the eight components. For example, targets can be established against the other markets when new markets are added to the assessment and benchmark (e.g. benchmark countries 1 and 2 in Figure 5). Countries 1 and 2 in Figure 6 are two hypothetical markets that are used as a benchmark for Qatar. Using this outcome, Qatar can set performance targets across the eight components and learn from countries that achieved relatively high maturities in such components compared to the others (e.g. noteworthy Publications from Country 2, Regulatory Framework from Country 1).

## 4. Conclusions

This research aimed to apply and compare two approaches for the analysis of market-wide BIM adoption: (a) the traditional survey based approach, and (b) specialised macro BIM adoption models. Both approaches were successfully implemented but the obtained results enable different understanding of market wide BIM adoption and have different practical implications.

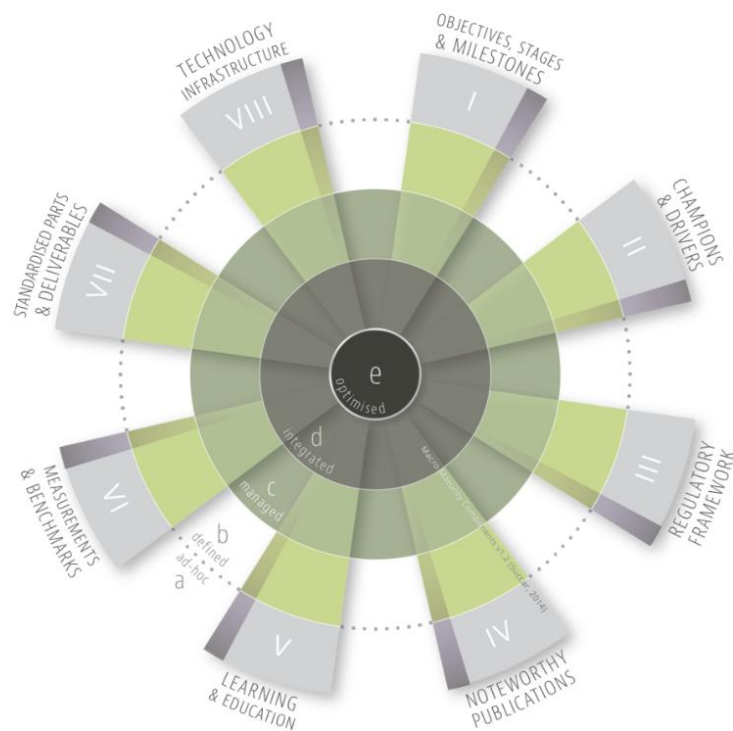


Figure 4: Macro-Maturity Components model (Succar and Kassem, 2015)

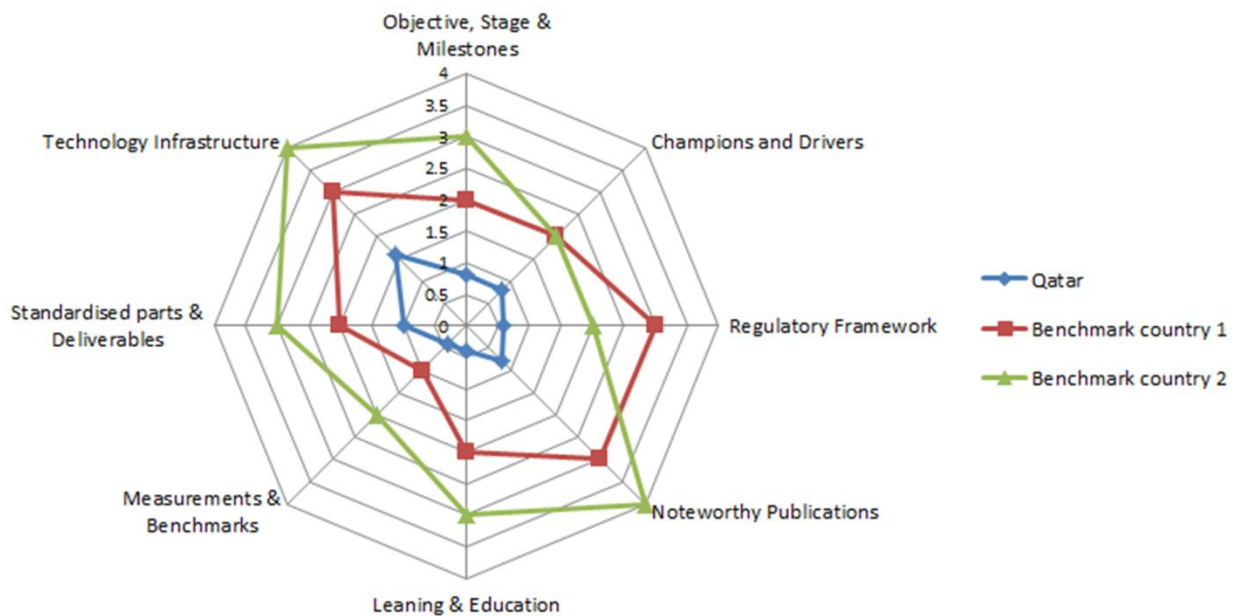


Figure 5: Rating of the eight maturity components in Qatar

The results from the survey/interview enabled an adequate general understanding of BIM adoption in Qatar. However, despite the improved structure (subdivision into topics: Technology, People, Process and Policy) and sampling methods (use of known sample of experts from key organisations operating in Qatar) of the survey/interview, the results remained descriptive and



qualitative. For example, the results identified: the different BIM technologies used in Qatar; the key issues in policy domain such as the lack of country-specific standards and protocols; the limited BIM learning and training opportunities within Qatar, among others.

The application of two macro BIM adoption models – i.e. Diffusion Areas model and Macro-Maturity component model – both enabled a more informative assessment of BIM adoption in Qatar and provided results that could inform policy actions. This is the result of using specialised models, each with a specific purpose – one model to assess diffusion areas and another model to assess the macro-maturity components – and corresponding metrics. Using these models, the macro BIM adoption can be benchmarked between two or more markets. One market can set specific improvement targets corresponding to the high performance achieved within another market, hence, promoting the learning process in BIM policy development across markets.

Finally, the two approaches can be considered complementary. The results from the traditional BIM survey-based approach can be used to explain or justify the rating obtained from specialised macro BIM adoption models.

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# Future of the multidimensional digital built environment

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## Abstract

The stakeholders of a built environment can attain several benefits by digitalizing the existing built environment. To highlight these benefits, this article presents a prototype of a digitalized built environment using 3D Internet technologies. To utilize existing data reserves and various measuring techniques, models of different levels of detail and accuracy must be combined, including existing location-based data, geographic information, building models, regional information, and infrastructure models. This raises a number of questions concerning novel types of GIS data, data integration and big data, interfaces, and availability and ownership of data. These questions bind the topic to the development of 3D Internet technologies. Finally, a smart city application architecture is proposed to enable the application development and increase the transferability of presented solutions.

**Keywords:** City model, digitalization, built environment, smart city, 3D map

# 1. Introduction

By using digital multidimensional models, many design and engineering tasks can thereby be performed in the digital domain. Three-dimensional (3D) models can be applied for various simulations and analyses. The underlying potential of this has led to the development of a megatrend within engineering. The built environment is likewise increasingly digitalized, both on the level of individual buildings and entire urban environments. Several drivers for digitalization in urban environments currently exist; simulations of different scenarios are required for increasing resilience. The limited existing resources for these call for new, more efficient ways of working. Finally, the smart city paradigm, with the emergence of 3D/4D city models is promoting digitalization (Hyypä et al., 2014a, Hyypä et al., 2014b).

Inside the building, the digitalization offers considerable benefits, such as improved quality assurance of construction, and utilization of integrated sensors to produce smart buildings (Firner et al., 2011). As the digital city models start to include more detailed models of buildings which include the exteriors, infrastructure, and surroundings, the realms of building and city modeling eventually intersect. Indeed, the first pilots are already being conducted where city models are updated to include the BIM models of buildings.

For larger urban areas, the digitalization of existing built environments is facilitated by 3D measurement techniques that make it possible to measure outdoor and indoor locations efficiently. For instance, depth cameras can be applied for indoor measurements (Du et al., 2011). Emerging measuring methods, such as laser scanning mounted on a person (Kukko et al., 2012) or unmanned aerial vehicle (UAV) (Lin et al., 2012), produce comprehensive 3D data sets from both the indoor and outdoor environments. In addition, the amount of data available from the environment is increasing due to the open data movement (Virtanen et al., 2015a). A third data flow is volunteered geo-information, enabled by mobile devices equipped with camera, GPS and Internet connection (Goodchild, 2007). For structures designed with building information modeling (BIM), the existing 3D models can be applied (Lang & Sittler, 2013).

As the data acquisition methods have developed, more emphasis is being put on automated processing of large data sets. Several algorithms have been developed for object detection from point clouds (e.g. Lehtomäki et al., 2010; Pu et al., 2011), classification (e.g. Antonarakis et al., 2008), and finally, automated modelling of the environment (Zhu et al., 2015). It is also possible to develop hybrid methods, which utilize both measurement data and existing data (Zhu et al., 2015). In addition, data from other sources can be combined to the city model to allow additional analyses (Hamilton et al., 2005).

To create a 3D model one can choose from multiple approaches and platforms, depending on one's needs and availability of data. There are nearly hundred different 3D modelling software to choose (some commercial ones like Esri's CityEngine, or Autodesk Revit but also freeware like Blender or freemium options like SketchUp).

After being created, the 3D models of the built environment can be applied to urban planning, architecture, and decision making in the urban environment (Döllner et al., 2006, Virtanen et al., 2015b). 3D city models can become a portal used to access urban information, the user interface to the digital city (Prandi et al., 2014). One of the applications for accurate 3D models of urban environments is the 3D cadastre (Rahman et al., 2011). The development of applications that utilize detailed models of the environment is stimulated by several technologies. Mobile devices have turned city models into a navigation tool and information portal (Burigat & Chittaro, 2005; Nurminen, 2006). Virtual reality technology is increasingly used for immersive applications (Beimler et al., 2013; Woodward & Sukittanon, 2015), also with city models (Engel et al., 2012). Virtual worlds and game engines are being used in development of various applications, including education (Potkonjak et al., 2016) and planning (Bishop & Stock, 2010).

When combined, the digitalization of the built environment creates a significant application potential, operating as a platform for new business models and value chains (e.g. Suwal et al., 2013, Underwood et al., 2010). The term “regional information modeling” can be used to describe this combination of expansive area models, accurate building models, and other data. The first phase in regional information modeling is the integration of existing location-based data, geographic information, building models, regional information, and infrastructure models with modern measuring technology and virtual elements (Hyypä et al., 2015). Figure 1 summarizes the aspects of future digital built environment; measurement techniques and data sources, processing methods, platforms and applications.

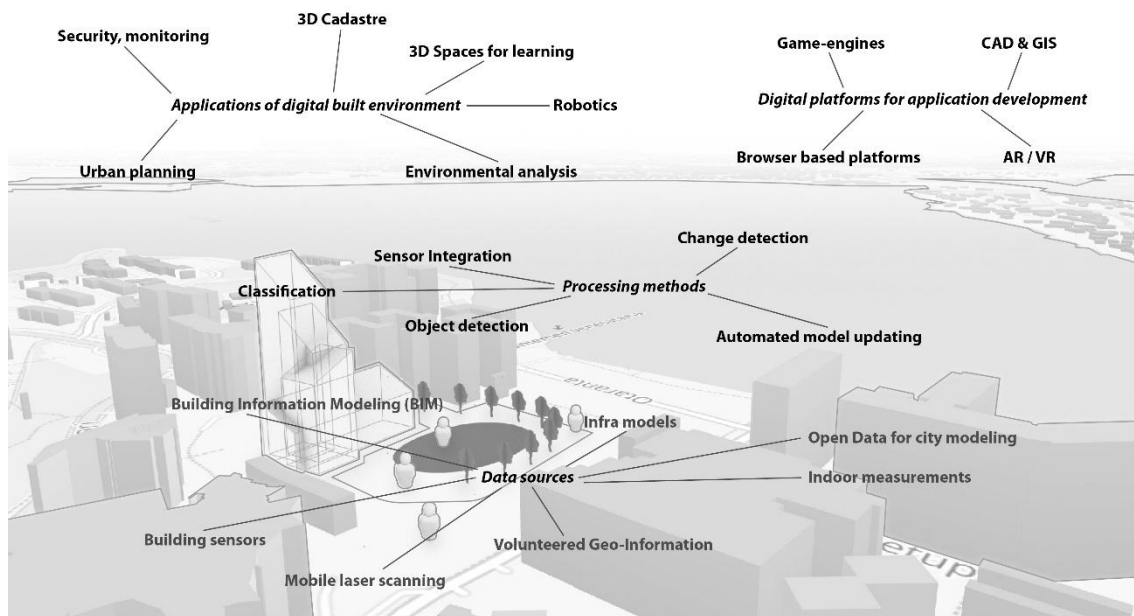


Figure 1: Aspects of the future digital built environment

Applications are a central component in value creation of digital models. In the context of digital built environment, platforms are required that support large city models and detailed building models while simultaneously allowing for application development. 3D application development platforms provide a beneficial starting point for this.

Our aim is to explore the concept of future digital built environment, by developing a prototype that combines the use of several different data sets on a 3D application development platform. There are several 3D modelling platforms and approaches, as mentioned earlier in the Introduction. For the purpose of this exploratory prototype we have chosen some typical set of data, including statistical data of a city and different types of building models, and a platform allowing the development of browser based 3D map applications. This article presents the results achieved.

## 2. Materials and methods

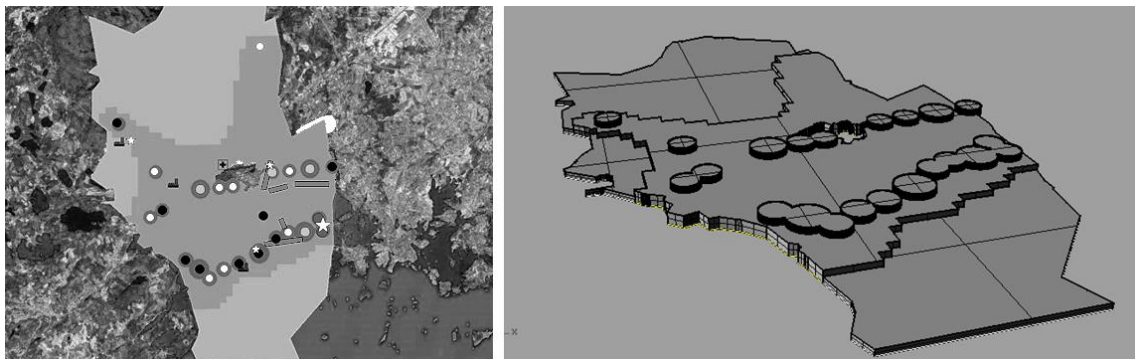
### 2.1 3D Internet application development platform

Meshmoon, a commercial development platform for virtual world applications, is based on open-source realXtend technology. The realXtend architecture is presented in earlier research by Alatalo (2011). Meshmoon and realXtend technology have been utilized to develop educational applications (Mattila et al., 2012), 3D cartographic applications (Virtanen et al., 2015a), and virtual city applications (Hyyppä et al., 2014b). To access Meshmoon scenes, it is possible to employ either a standalone or browser-based client.

The background maps and simple building models were obtained by using the Meshmoon Geo plugin (later commercialized as MapGets). The plugin obtains a simple terrain model with a set of alternative textures (eg. aerial image, properties map, and background map) and Level of Detail 1 (LOD1) building models over the WFS interface from the city data sources.

### 2.2 Espoo regional planning data

A set of regional planning data from the City of Espoo was converted to 3D and uploaded to the platform. The original data was in the Map Info format. For point data, columns were created to visualize the table values. For polygons, corresponding mesh models were built in the Rhinoceros 3D modeling suite (Figure 2). Thereafter, a small application was written for the Meshmoon platform to change the heights of the mesh models to visualize statistical data related to regions.

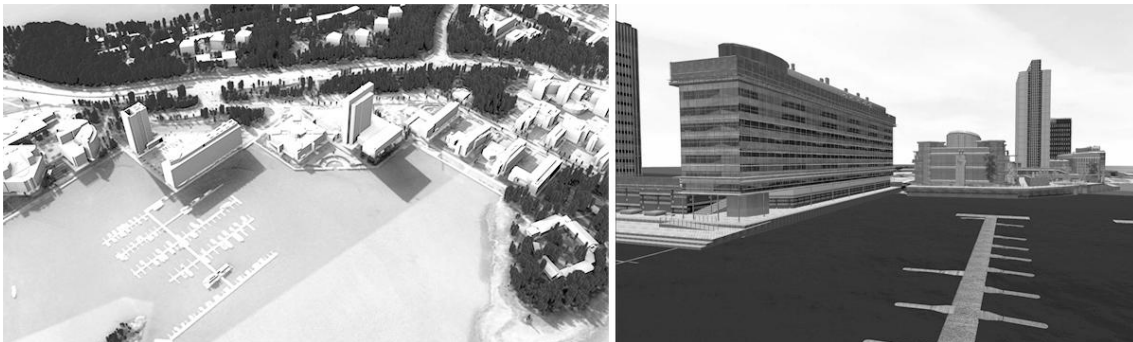


*Figure 2: Original data and the resulting 3D equivalent*

## 2.3 Keilaniemi area models

Two area models depicting the Keilaniemi area in Espoo were used in the experiment. ALS data from the Keilaniemi region was applied to produce a LOD 2 model of the area (Figure 3). A digital terrain model (DTM) of the area was textured with aerial images. In addition, building models were produced by automatic building vectorization. Tree parameters for the area were extracted from ALS data, and utilized to produce a visualization of the trees in the area by duplicating the same simplified tree model.

To produce a more detailed model from a part of the Keilaniemi shore, a set of commercial high-rise buildings was modeled using both aerial and mobile laser scanning data sets as a reference. The goal of this was to produce a near-photorealistic representation of the area. The results of the automated building vectorization were employed as the starting point for more detailed modeling. Typical methods from the computer gaming industry were utilized to create content. For example, materials included in the models use tileable bitmaps, and material properties have been added to surface through other bitmaps, such as specularity, surface normals, and reflectance. The subsequent measurements performed with MLS were completed in only a few hours, after which some additional time was required for processing the data. However, the modeling work required several weeks of working time from an experienced modeler. Originally, the scene was built using the Unity game engine, and the models were crafted in 3ds Max. The completed model was then transferred to the Meshmoon environment (Figure 3).



*Figure 3: Virtual Keilaniemi shore, showing the LOD 2 model (left) and the near-photorealistic model (right)*

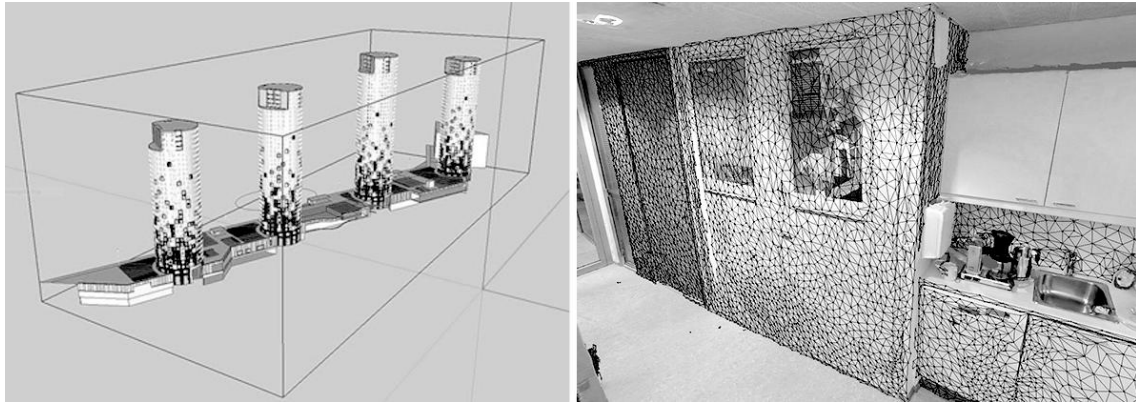
## 2.4 Building models

A model of the Keilaniemi Towers project was used as an example of a 3D CAD model. The model was converted from its original SketchUp format and uploaded to the platform. The position of the model was solved from the regional plan provided with the model. The model contained the simplified exterior of the proposed project, as it was envisioned in the early planning phase of the area (Figure 3).

In addition, a depth camera-based indoor measuring device, Matterport (2015), was utilized to produce a detailed and textured 3D model of a small office space in Espoo, Finland. To achieve this, several camera positions were employed to measure the space; the resulting measurements



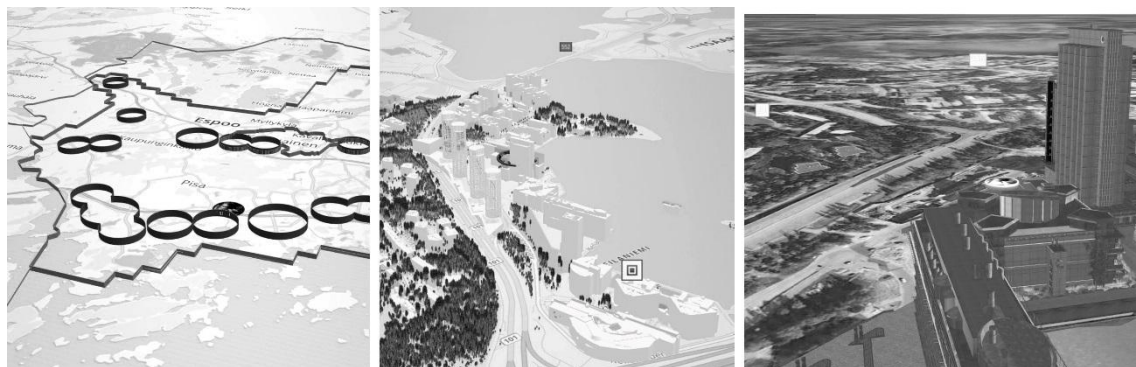
were performed in less than an hour. The time required for the automated modeling was not recorded; however, the model was available on the day following the measurement. The automatically produced mesh model was transferred to Meshmoon via the Unity platform (Figure 4).



*Figure 4: The building model of Keilaniemi Towers (left) and a detailed model of an office environment (right)*

### 3. Results

By using the developed processing methods, it is possible to visualize all of the previously described data sets on the same virtual 3D map. The models have been divided into components that can be separately toggled on or off. For example, the vectorized building models from the ALS data set can be used with or without the textured terrain model. The building model from the Keilaniemi Towers project can be studied either on a properties map, typical background map, or a DTM textured with aerial images (Figure 5). The regional planning data from the city can then be visualized on top of these models.



*Figure 5: Regional data (left), LOD 2 model (middle) and fotorealistic model (right) rendered in Meshmoon on top of the 3D map*



### 3.1 Future smart city architecture

Figure 1 presents a set of aspects of the future digital built environment, including the measuring methods utilized to obtain the data, models produced, and finally applications of these models. As stated in the introduction, the emerging measurement methods, such as mobile laser scanning and UAV-based laser scanning, are able to produce comprehensive data sets from the existing built environment. For efficient utilization of these techniques, it is necessary to implement automated modeling workflows. By combining efficient measurements with automated modeling, the detailed 3D city model can be produced to operate as the starting point for smart city applications. After this, other data sources must be integrated into the model. This includes data from various sensors and other city data systems. Finally, the model can be transferred to an application development platform for use in applications. However, if the measuring and modeling pipeline is repeated for each application, the amount of redundant work becomes too high. To increase the cost effectiveness of applications operating in the digital built environment, an architecture is required that allows for the transfer of applications from one area to another. Additionally, to detach specific applications from the data sources, homogenous models have to be produced from varying sets of starting data.

To overcome these challenges, this article proposes an architecture for application development in the future digital built environment. In this, an intermediate smart city platform layer is added between the data sources and 3D application authoring platform (Figure 6). The proposed smart city application layer consists of the following components: an automated modeling pipeline, data integration, and model authoring. In the automated modeling pipeline, 3D models of the environment are created from the source data. Data from other systems, such as city GIS, is combined with these 3D models in the data integration stage. Finally, a model compatible with 3D application development platforms is exported in the model authoring step. Following this architecture, the existing 3D application development platforms can be employed to produce the specific smart city applications. This serves two purposes: firstly, it enables the use of generic 3D platforms (e.g. Unity) for creating and publishing smart city applications and secondly, it creates distinct boundaries between the source data, model, and application. This increases the transferability of produced solutions to all regions from which suitable source data is available. This permits an easier transfer of solutions, and lowers the threshold for wider adoption of solutions piloted in test regions, thus supporting pioneering activities (Markkula & Kune, 2015, Virtanen et al., 2014).

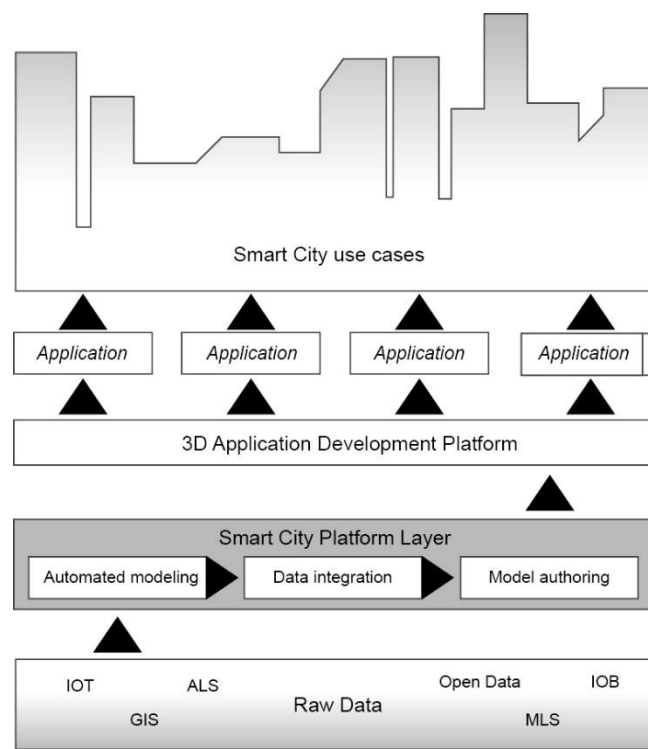


Figure 6: The future smart city architecture

## 4. Discussion

With current technologies, it is possible to create digital equivalents of built environments that can be applied to a variety of tasks, such as urban planning. To reach the benefits described in the introduction, the digitalization of the built environment must be carried out with a wider scope. 3D digital models can be produced by measuring the existing physical environment, for example with aerial laser scanning (ALS). Moreover, the development of automation in 3D modeling is accelerating digitalization and reducing costs. For the new urban areas under development, this 3D data is readily available as a result of BIM. Furthermore, 3D GIS are needed for analysis of energy consumption, solar energy potential, accessibility, visibility and 3D position of apartments in high rise construction, for example.

With the currently available tools, generating a simple 3D map can be largely automated, if suitable data sources are available. In the Finnish context, the open data repositories enable the generation of DTM from open ALS data. However, the degree of automation decreases when the data types start to vary from cartographic entities (such as building footprints and road contours) to statistical data, which may or may not contain physical areas defined as polygons. In this case, the workflows must be adapted to each data set. Nevertheless, as long as the statistical data is bound to a known coordinate system, the processes can in theory be automated. For models that do not contain information of their location and orientation in a known coordinate system, the only remaining alternative is to perform an interactive orientation. This concerns both building models that are in an unknown local coordinate system, and indoor models that cannot be easily georeferenced with GPS for example.

The computational requirements of the system increase with the amount of data. With the described models, the visualization system remained operational in a web browser (Google Chrome) with a high performance laptop (Intel Core i7, 2.7 GHz, 16 GB ram). Thus, optimization

methods must be applied to enable improvements to the detail level of the models or the modeling of larger areas.

In the presented demonstration, all the data was uploaded to the server by a single user. In this research project, the ownership and publicity of the data sets did not cause any conflicts. However, if the presented system is to be used by more stakeholders, there is a need to address these potential ownership issues. In addition, if the data originates from several providers, some quality assurance methods have to be applied. Another issue encountered in the presented demo is the merging of several overlapping data sets of different detail levels and accuracies. Therefore, methods should be applied that allow for the intelligent integration of these data sets. These issues become most pronounced when an individual building is represented in several data sources. In such cases, it would be beneficial to identify the building from all data sets and define several LODs for its model.

It should be noted that there are alternatives to the utilization of 3D models in an urban context. Firstly, linked and georeferenced panoramic images have been used in previous research (Nebiker et al., 2010). A well-known commercial example of this type of “modeling” is Google Street View. A second possibility is the utilization of dense, colored point clouds. This can be considered to be an alternative paradigm to modeling: instead of building models based on points, edges, and surfaces, the system focuses on segmenting the point clouds and combining the semantic information directly to them. The notion of building virtual environments from point clouds has been previously presented by Nebiker et al. (2010). However, breaking away from the paradigm of modeling would be a significant change of direction in the city model discussion and would make existing modeling workflows and model formats obsolete.

## **5. Conclusions**

By adopting an existing application development platform, it is thereby possible to merge different models and study their subsequent combinations. For example, a 3D map of the area with buildings of an ALS or MLS-based model can be combined with a CAD model of a building being planned. These combined models can thus already be applied to decision making and visualization.

By using 3D application development platforms, multi-user visualizations that operate in a web browser can be built from these diverse data sets. Commercial platforms (MapGets) have already been released that can automatically produce a background map for such applications. By applying these, such visualizations can be achieved more efficiently than by just applying them with a game engine. These technologies are the key to a wide area of potential applications that can be developed in the future.

The development and prototyping of digital 3D platforms that simultaneously support large area models and detailed building models pave the way for the future merger of 3D Internet technologies, BIM, civil engineering, urban planning, and volunteered location-based information.

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# Innovative Industrialised Buildings: Performance, Perceptions, and Barriers to Financing associated with Building Manufacturing

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## Abstract

Most buildings are still constructed one brick or timber at a time, over lengthy periods on-site, much like ancient civilisations. This paper poses the question of whether the manufacture of buildings using digital and production line techniques from advanced manufacture can transform building to be less wasteful, quicker, more affordable, and more sustainable. This is an important question as the innovative industrialisation of buildings presents a significant opportunity for the building and construction sectors worldwide. Findings suggest that between 2011 and 2012 the economic output from the industrialised manufacture of buildings globally increased by a staggering 50% to just over US\$90 billion, with nearly half of this manufactured in the Asia-Pacific region. The paper points out that there is great potential for the manufacture of buildings to be harnessed to significantly strengthen both the building and manufacturing sectors. The research suggests that domestic building industries around the world will face strong international competition in the near future, especially as the quality of imported prefabricated and manufactured building offerings is increasing and the price is decreasing. However the transition to manufactured buildings must be undertaken in such a way as to harness a nations existing pool of skills and trades so as to allow workforce transitioning in a manner that strengthens industry. The paper highlights a number of challenges to upscaling building manufacture related to finance, insurance, and warranty structures, and presents potential options for overcoming such barriers. This paper presents findings of research undertaken as part of a Sustainable Built Environment National Research Centre (SBEnc) in Australia in collaboration with the Cooperative Research Centre (CRC) for Low Carbon Living

**Keywords:** Manufactured Buildings, Innovation,

# 1. Introduction

There are numerous economic, social, and environmental benefits associated with building manufacture or offsite construction. This presents a lucrative opportunity for the construction and advanced manufacturing industries. According to research by the Australian Sustainable Built Environment National Research Centre (SBEnc, 2014), new approaches to design, materials, and expanding the use of modular techniques can take advantage of faster fabrication times, lower costs, less waste, high quality standards, and shorter onsite construction periods. According to the research benefits of shifting to an offsite construction and fabrication model include:

- *Reduced Costs:* Faster construction times together with reduced delays from delivery, coordination, and inclement weather lead to reductions in project cost, including: cost of finance, insurances, hire equipment, plant and equipment fuel, and staffing costs, also reducing homebuyers need to pay rent.
- *Increased Safety:* Significantly improved workplace occupational health and safety by bringing the majority of building construction indoors and providing 24 hour lighting and climate control. Easy use of platforms, mini-cranes, wheeled scaffolds, and harnesses.
- *Materials Benefits:* A central facility allows for 24 hour receipt of bulk orders with secure storage which will reduce costs and delays. Materials can easily be reused which can reduce waste by 30-40%, reducing wasted materials and dumping costs - some 40% of landfill in Australia is derived from construction waste.
- *Access to Services:* A central facility allows for line-side services such as scaffolding hire, materials stores, tool shops, building component manufacture (such as window frames), and access to fixed cutting and fabricating equipment (rather than on-site handheld equipment).

In Australia, the construction of buildings offsite for onsite assembly dates back to the first set of portable iron clad homes constructed in the UK and shipped to Melbourne in the 1850's. Decades later the aftermath of World War II created conditions of abundant building materials and an urgent need for rapid rebuilding, leading a number of countries to turn to prefabrication of buildings. The first housing manufacturing plant was created in the United States in 1926, followed by the UK, and Japan in 1955.

However despite such benefits and the early uptake of building manufacturing processes the current level of offsite construction and prefabrication of buildings in Australia is low, representing some 3 percent of the value created by the Australian construction industry. This low level of uptake not only forgoes associated benefits but also opens up business to the threat of imports from the region, with Australian imports of buildings anticipated to reach a value of \$30 billion by 2025, displacing around 75,000 jobs nationally. In 2012 the economic output from the manufacture of buildings globally was estimated at just over US\$90 billion, up from \$60 billion in 2011. In 2014 the largest regional market was Asia-Pacific valued at US\$44.4 billion, followed by Europe at US\$31.5 billion, and North America at US\$10.2 billion (Research and Markets, 2014). The growing number of case studies and examples of manufacturing buildings provides



quantifiable data that can inform efforts to capture the opportunities by providing strong evidence to developers, investors, and homebuyers.

However the transition to manufactured buildings must be undertaken in such a way as to harness the existing pool of skills and trades so as to allow workforce transitioning in a manner that strengthens industry. Further a number of challenges will need to be faced such as issues related to finance, insurance, and warranty structures. For instance, until recently the Queensland Home Warranty Scheme that protects consumers and builders excluded '*offsite prefabrication in a factory of the whole of a building*' (BSA, 2011). There are a number of barriers to finance that need to be overcome, namely:

- *Progress Payments:* In order to provide the access to capital needed to significantly upscale building manufacture, and capture the associated benefits, long standing financing structures need to be rearranged in the building sector that are on progress payments at different stages of onsite construction rather than being able to support factory style construction prior to transportation to site of completed product for erection. Issues related to the lack of a standardised quality assessment process for offsite construction along with gaps in current building standards and codes complicate matters.
- *Completion Risk:* There is also uncertainty around managing completion risk, such that the building is in the possession of the manufacturer up until delivery and may not be able to be easily completed should the manufacture halt operations (this may be affected by issues related to intellectual property of manufacturing methods hindering a shift in manufacturer if required). This also presents a risk to the builder or manufacturer as clients may not provide purchase confirmation until the building is delivered and able to be used for collateral for loans, leaving open the potential to withdraw part-way through the offsite construction or not being able to secure a loan at time of delivery.
- *Warranties and Defect Rectification:* There is a need for a clear and accountable process for the rectification of defects, especially when sourcing building modules from overseas, along with insurance and warranty structures that support offsite construction and onsite erection. The allocation of responsibility for defects is complicated by the nature of the offsite delivery model in that it can require multiple contractors to undertake offsite construction, module transportation, and onsite preparation and assembly, with each stage able to identify defects and warranty issues.

This paper investigates if the performance of manufactured buildings is superior to onsite construction methods, and considers ways to overcome barriers to financing in an Australian context.

## 2. Why does building manufacture present an opportunity?

### 2.1 Benefits of offsite construction

The shift to the manufacture of buildings stands to reduce a number of impacts including economic (reducing the time homebuyers rent while their home is constructed), social (significantly improving workplace occupational health and safety by bringing the majority of building construction indoors), and environmentally (through reduced materials wastage, reduced materials transportation, greater inclusion of energy and water efficient elements, and the potential for greater use of recycled materials). Research by the Australian Sustainable Built Environment National Research Centre (SBEnc, 2014) has shown that building manufacture allows for cost savings, faster delivery times, and the reduction of a number of impacts associated with on-site building construction methods, such as:

1. *Cost Savings:* The shift to prefabrication of buildings stands to deliver a range of cost savings to developers, builders, and owners. The greatest cost benefits are achievable in projects where replicable structures are used, such as apartments, housing developments, hotels, student accommodation, classrooms, prisons, and mining accommodations. Direct costs savings are achieved from the faster delivery of buildings using prefabrication methods, along with reductions in construction waste both from design and higher reuse of materials, weather damage of materials, damage caused from onsite handling in often restricted sites with multiple trades, and the elimination of vandalism and site theft during construction. The potential for such savings opens up the opportunity for the greater provision of affordable and social housing along with the provision of a higher level of quality and non-standard inclusions in residential and commercial buildings. In particular it would make 'sustainability' related inclusions that can deliver lower operating costs to occupants and owners more economically feasible at the construction stage (especially energy related inclusions). Not only is there significant potential for cost savings it is likely that due to a manufacturing approach being taken that rewards reducing variations that the initial price of the building is close to the final price, whereas onsite construction enjoys the ability to incur variations that add to the cost of the project.
2. *Faster Delivery:* The shift to the manufacture of buildings stands to significantly reduce construction times, along with reducing onsite delays often caused by waiting for materials delivery, coordinating service providers and subcontractors, and from inclement weather. Reducing construction times can lead to a range of benefits such as reducing the cost of fees on land taxes, equipment hire, fuel bills, and staff on-costs. The shift will also allow a greater volume of buildings to be delivered as not only is the construction time shorter it can be carried out at the same time as site preparation (i.e. footings, retaining walls, and landscaping). This is important as the shift is likely to reduce the labour requirement of individual buildings so it will be important to compensate with a growth in building output.
3. *Improved Work Place Conditions:* The shift to the manufacture of buildings in dedicated facilities will provide a number of improvements to workplace conditions, including:
  - Protection from weather and other hazards for both workers and materials, along with the provision of appropriate lighting levels 24 hours a day,

- Provision for use of central power tool facilities rather than the reliance on hand tools or portable power tools onsite, and
- Greater ability to provide elevated platforms, mini cranes, roped harnesses, and other safety equipment due to construction undertaken in a fixed facility with flat floors and overhead beams.

Furthermore, the shift to a centralised facility leads to a number of benefits such as greater flexibility in supplier choice as materials can be stockpiled rather than being needed on demand at multiple sites across a city or region, a regular delivery location with dedicated loading bay facilities reducing transportation costs of supplies, and the assurance that there will be someone to sign for materials at the facility.

## **2.2 What is needed to accelerate building manufacture in Australia?**

Despite the opportunities there are a number of challenges to overcome, both real and perceived, in order to mainstream building manufacture, especially in Australia. For instance there are lingering mis-perceptions around the costs involved in building manufacture and the ability to produce high-end homes and commercial buildings. In the past, manufactured buildings have often been perceived to be only used for site huts or temporary transportable rooms or offices which are common in Australian construction sites, mines, and schools, however the latest market offerings allow for high quality precision designed buildings to be produced. Along with such perceptions that need to be addressed, the shift to aggregating construction of buildings to dedicated facilities to be transported to site for erection presents a number of challenges to be addressed in order to progress the industry, namely:

### *Perceptions of Quality*

- There is a need to shift perceptions of the industry and consumers around manufactured buildings being simply temporary reloadable structures to recognising them as high quality precision built buildings; this may be through independent quality verification, demonstration buildings, community education programs, and qualifying the specific benefits to consumers.

### *Design Processes and Controls*

- There is a need to ensure that design, construction, and erection processes harness the full potential of the building manufacturing model and allow a streamlined delivery. This may include the updating of design codes and standards and associated changes to education and skills development programs. Key areas for consideration include ensuring interoperability of standardised components and avoid re-invention of design practices by competing companies which may hinder the overall industry.
- There is a need to re-evaluate building project management processes related to materials and goods and services supply models to capture benefits from constructing multiple buildings in one location concurrently, such as being able to stockpile building materials and cluster buildings for sub-contractors to work on multiple buildings on one site.

- There is a need to standardise building transportation requirements and restrictions at a national level to allow for greater ease in interstate transportation of manufactured buildings or components.

#### *Supply Chains*

- There is a need to effectively engage with small businesses involved in building construction to shift from individual building contracts on various sites to a clustering of skills to deliver multiple building projects from a centralised factory-style facility. There is a need to also engage with advanced manufacturing business to assist in a transition from sectors such as the auto industry to supporting the building manufacture industry.
- There is a need to develop efficient and effective building transportation and erection processes and equipment to minimise associated costs and maximise accessibility to various site conditions. This will involve the building industry working with trucking and crane companies to a much greater extent.

#### *Financial Models*

- There is a need to address impacts on completion risks such that the building is in the possession of the manufacturer up until delivery and may not be able to be easily completed should the manufacture halt operations, or the client may not qualify for finance or withdraw part way through the construction process.
- There is a need to overcome in collaboration with banks and financial institutions the resistance to rearrange long standing financing structures that are based on progress payments at different stages of onsite construction to support factory style construction prior to transportation to site of completed product for erection.

#### *Defects and Insurances*

- There is a need for a clear and accountable process for the rectification of defects, especially when sourcing building modules from overseas. Further there are issues of the allocation of responsibility for defects given that the buildings can be constructed, transported, and erected using different contractors.
- There is a need for insurance and warrantee structures to support offsite construction and onsite erection.

#### *Skills Development and Transitioning*

- There is a need to provide capacity building to trades to adapt to building prefabrication, this may involve both the development of training courses and programs along with incentive schemes to encourage up-skilling.

### 3. Perceptions of Manufactured Buildings

#### 3.1 What is the perception of manufactured buildings?

PrefabAUS Chief Executive Officer Warren McGregor believes the single biggest challenge for embracing manufactured buildings within Australia “*will be the change in mindset involved*”, with this change needing to be “*widespread; including clients, contractors, architects and consultants, project managers and suppliers*”. The lack of appreciation of the quality now possibly from manufactured buildings stems from the poor reputation of post-World War II social housing projects both in Australia and internationally. The pressing requirement for rapid rebuilding after the war years created an environment in which factory built structures came to the fore as they provided a low cost means to provide a high number of residential properties in a short time frame. While generations may have passed since then, a lack of knowledge has caused poor market perception of manufactured buildings to remain within Australia.

This negative bias has been increased through the association of prefabricated buildings with mobile and trailer homes, low socio-economic housing projects, temporary institutional buildings such as demountable classrooms and worksite offices. In a study by Steinhardt, Manley and Miller (2013) an Australian industry representative reflected that prefabricated buildings within Australia have on the whole been “*pretty cheap, nasty, flimsy, lightweight constructions*”. Such associations have resulted in misconceptions about the quality and durability of manufactured buildings and has led to prefabricated buildings being seen as inferior products to traditional on-site constructed buildings, which is not in-fact the case. It is common for consumers to think of prefabricated buildings as standard sized shipping container like volumetric boxes. But prefabricated buildings have come a long way since those transported from London to Sydney in the early 1800s. Building manufacture now encompasses a wide range of off-site fabrication of components (for example frames and wall panels), subassemblies and volumetric modules that can be used across a broad spectrum of projects including residential homes, commercial buildings, hotels, apartments, offices, educational facilities, hospitals and worksite accommodation.



Figure 1: Adara Apartments, Western Australia (compliments of Housing WA)

### 3.2 How can the perception be changed

It is important for prefabricated buildings to use innovative design and new technology to be able to disassociate with traditional box-like features and change the current market perception. One such example, The Adara Apartments in Western Australia has achieved this (as shown in Figure 1). Designed by Campion Design Group and built by Hickory over a 12 month period, this building is a success story for the prefabricated building industry. Once the initial foundations and amenities were laid, 96 prefabricated modular components were brought and installed over a 10 day period. This structure boasts a reduction of 10- 12% less in construction costs, 35- 40% less aggregate funding costs and improved return on equity for investors. Despite new prefabricated buildings rising in cities around the world, the slow growth of prefabricated residential buildings is due in large to the reluctance of consumers to move away from traditional on-site building methods. In a US study into consumer perceptions of residential building methodologies in 2007, on-site built homes were more favourable than prefabricated homes, rating highest with '*respect to quality of construction, resale value, availability of financing, quality of surrounding neighbourhood and the look and feel of the home*' (HUD, 2007). Of these considerations, the perceived quality of construction was the most influential concern that consumers had when selecting building methodology. Additionally, consumers largely select traditional building methods as they provide for a sense of reliability and security. However manufactured products like 'The Auburn' in Australia shown in Figure 2 are changing the perception of the level of quality available.

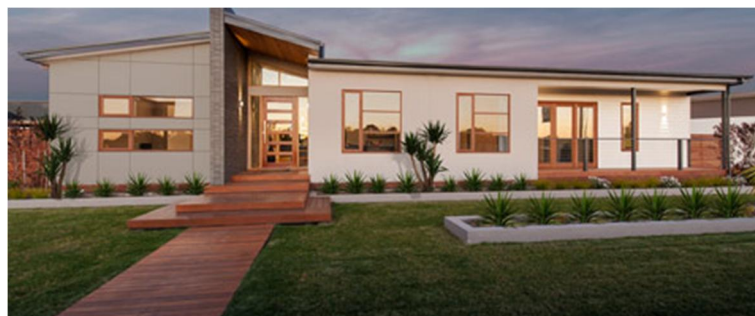


Figure 2: The Auburn (compliments of Allsteel Homes, Australia)

Shifting negative perceptions of manufactured buildings from temporary, low quality structures to high quality precision designed buildings is critical to increasing market share. However the marketing of prefabricated building needs to be carefully considered as despite being clearly more affordable and able to be delivered in much shorter timeframes using terms like 'low-cost' and 'fast' may resonate with perceptions of low quality. Terminology surrounding manufactured buildings can also impact perceptions of quality. Terms such as 'Modular' or 'Prefabricated' tend to again have associations with low quality buildings from the past, with companies now not making a point of the construction method but rather the quality, timeframes, and price.

The Japanese building sector has taken a targeted approach with companies such as Sekisui House, Sekisui Heim, Misawa Homes, and Daiwa House targeting upper socio-economic and environmentally conscious clients. These prefabricated models available are continuously analysed and improved with qualities such as thermal efficiency and energy consumption as well

as seismic and acoustic performance. This strategy generally means a higher upfront capital cost do to the improvements but builds the reputation that efforts are being constantly made to reduce operating costs over the lifespan of the building, such as from energy and water consumption.

## **4. Overcoming Barriers to Financing Building Manufacture**

### **4.1 Construction phase financing**

The most often mentioned barrier to financing building manufacture is that as the construction phase takes place in a private facility, rather than onsite, it is difficult to use financing mechanisms that have been established to support onsite construction. Further as the value of the manufactured product is substantial compared with other manufactured goods a series of progress payments is preferred by builders. Hence the conflict between capturing the benefits of offsite construction and accessing progress payments using current financing arrangements presents a significant barrier to the upscaling of building manufacturing. This is due to the fact that unlike onsite construction, where the partially completed building is in the custody of the owner or developer and therefore forms collateral on the loan, using an offsite model calls for progress payments to be made while the building remains in the custody of the builder in a private facility.

Lending institutions are however accustomed to releasing funds for buildings constructed offsite after the building has been placed on site. The stage at which funds are released varies between lenders from when the building is installed on approved footings to when a certificate of occupancy has been issued. Hence the issue of progress payments is currently being overcome by developers, or even the building manufacturers, providing the funding required for the construction phase to then allow customers to seek purchasing finance based on the completed building. Although this model allows for the client or owner to secure traditional loan products based on a completed building there are two drawbacks that are hindering the growth of the industry. Firstly it lends itself to large companies who can afford to provide construction phase financing, with smaller operators having to mortgage their own assets (or requiring customers that have appropriate assets to leverage), and secondly it means that the risk is carried by the builder or manufacturer until payment is made. Since the purchase finance cannot be secured prior to the construction stage this leaves the builder open to risks like the customer not being able to secure funding after the building is complete, or having the client change their mind before the building is completed.

### **4.2 Providing assurance of quality**

A key element in ensuring the quality of buildings constructed offsite using prefabrication and/or manufacturing based processes is the provision of associated design codes and standards that can be assessed for compliance. In the USA, the U.S. Department of Housing and Urban Development can create a construction and safety standard for offsite construction and building manufacture, the '*Manufactured Home Construction and Safety Standards*'. This standard classifies a manufacture home as one that is '*constructed on a permanent chassis*' and provides standards for design, construction, and installation of manufactured homes to assure the quality, durability,

safety, and affordability. The standards include a dispute resolution component along with the provision for inspections and record keeping.

A second key way to provide assurance of quality is through the provision of a warranty or assurance scheme. For example in Japan, where prefabricated housing represents some 13 percent of the building stock, building owners are provided with a standard 20 year warranty which entails strong after sales service. In the UK efforts to increase the viability of securing construction financing have focused on providing independent certification of the processes used in offsite construction and building manufacture in collaboration with the Council of Mortgage Lenders. The '*Build Offsite Property Assurance Scheme*' (BOPAS) seeks to provide assurance to lending institutions that buildings constructed offsite are sufficiently energy efficient and durable and will be readably saleable for a minimum of 60 years. The BOPAS certification process consists of two components:

- (1) A *durability and maintenance assessment* that provides an independent technical assessment of the building's suitability and encompasses issues relating to reparability, maintainability, and suitability for housing (or other building types).
- (2) Accreditation of *the design and/or construction processes* that is solely risk based, in which designers, manufactures and constructors are evaluated on key performance areas at each stage of project development from concept design to project completion. The major performance areas are: risk management, competency management, configuration management, procurement management, and process control.

The process accreditation occurs in two stages. An organisation initially undergoes a gap audit in which any significant weaknesses are highlighted and adoption of best practice is facilitated. A full implementation audit is then undertaken in which key performance areas are examined against a best practice standard, with accredited organisations undergoing regular visits to ensure proficiency is maintained. A key feature of the BOPAS system is the use of an online database that provides valuers, lenders and surveyors a single point of reference to find all accredited designers, manufacturers, constructors and building systems.

### **4.3 Provision of loan insurance**

In the USA, the provision of government-insured mortgage loans offered by the Federal Housing Administration encourage mortgage lenders to finance manufactured homes by protecting the lender against the risk of default from the buyer. Traditionally, manufactured homes have been financed as personal property through comparatively high-interest, short-term consumer instalment loans. Mortgage lenders have now established appropriate products that allows buyers to finance their home purchase at a longer term and lower interest rate than with conventional loans. The buyer pays an upfront insurance premium, along with an annual premium based on the declining balance of the loan. The maximum loan term is 20 years for a manufactured housing loan. Despite such progress a study has found that from 2001 to 2010 in the United States an estimated 65% of manufactured housing customers who owned their land and took out a loan financed their purchase with a chattel loan, which is a secured loan where the financier takes



charge over the asset. Although chattel loans have lower initial costs and may close sooner than mortgages, interest rates on chattel loans, however, are usually higher and chattel loans generally have lesser consumer protections than mortgages. Overall, customers buying prefabricated homes tend to pay higher interest rates for their loans than ordinary home buyers. In 2012, according to the Consumer Financial Protection Bureau (CFPB, 2014) approximately 68% of all manufactured-housing purchase loans in the USA were classified as high-priced mortgage loans.

#### 4.4 Issues related to defects and contractual arrangements

Further to issues related progress payments there are issues related to the responsibility for defects given that the construction of the building is now undertaken in two stages that may involve different contractors. The first stage is the offsite construction stage to produce building components or modules, and the second stage is related to onsite construction, such as site preparation, construction of footings and building core, and transportation, lifting, and assembly of building modules. At each of these stages defects can be present and the responsibility for defect identification and rectification is not always clear cut which can lead to conflict between parties. Litigation can arise between the manufacture and the installer in cases where the contractual responsibility has been divided between the two, where both parties are likely to point the finger at one another over delays and defects.

The potential for such issues can also be of concern for lending instructions, causing a barrier to finance, however this can be overcome through a 'Design and Construct' contractual arrangement. In such an arrangement the builder or developer will undertake the design and enter into a subcontract with a manufacturer who will produce the modules. The builder will undertake associated on-site construction and installation of the modules. Within such a contractual arrangement, there is a single point of responsibility whereby the builder is accountable for all design, construction and manufacturing faults and defects. The manufacturer of the modules or building components is responsible for rectification of defaults as if it were any other subcontractor.

## 5. Conclusions

The manufacture of buildings has the potential to provide high quality and cost-effective houses, apartments, office blocks and a range of other building types, utilising the technologies, materials, design knowhow, and construction experience currently in the both the building and manufacturing sectors. This together with the benefits pointed out previously suggest that it is likely that a large part of building construction will shift from individual buildings constructed onsite to the aggregation of construction in dedicated facilities to be transported for erection on site. Manufactured buildings are unlikely completely replace conventional building approaches, but they stand to significantly increase share in the market, particularly for multi-storey buildings. As with a number of other advanced industries, such as renewable energy technology, the slow recognition of the value that can be created through the manufacture of buildings in many countries such as Australia may lead to a missed opportunity with off-shore providers dominating the nation's future building market.

In order to capture the potential of building manufacture the building sector needs to quickly develop the infrastructure for the construction of buildings in centralised facilities and their transport and erection on site. This may involve a transition strategy that includes an initial push for the use of panelised onsite construction to build momentum in the manufacture and erection of prefabricated components and modules. It is particularly important to develop the sector in a manner that takes advantage of the cost effectiveness of sourcing building modules off-shore, otherwise such offerings will compete with domestic construction. There are already cases of off-shore building manufacturing plants that are importing Australian electrical and plumbing components to ensure that standards and codes are met when shipping to Australian customers. Hence, if countries like Australia do not seize the opportunity of building manufacturing, foreign companies will certainly continue to bring them to market, which if not harnessed as part of the sectors overall development could lead to job losses across the building sector and its supply chain.

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# Economic Value and GHG emissions of the residential Internet of Buildings in Finland

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## Abstract

Digitalization is a megatrend that is expected significantly to raise productivity across sectors. Among others, buildings and real estates sector possesses untapped economic and resource efficiency potential that may be reached with digitalized solutions. One of the most significant obstacles preventing the potential to realize is the restricted or non-existent sharing of information between buildings and real estate stakeholders. The Internet of Buildings (IoB) provides a solution for enabling the existing potential in buildings and real estates by networking buildings and real estate service stakeholders with information, energy and resource flows. The study introduces a definition for IoB as “an ecosystem of buildings, users and service providers using smart buildings as an enabling technology”. This research estimates the economic value of IoB in Finnish markets. The economic value is estimated using statistical expenditure data of public and private consumption related to IoB related activities. Since the sector is also a big contributor to the climate change, the GHG emissions caused by the sector are analysed and the sub-sectors contributing most to climate change are identified. According to the study, the economic value of IoB-relevant consumption is around €70 billion per year, which accounts for major share of public and private consumption. The housing and public welfare services were the sub-sectors contributing the most to the economic value. Energy consumption, including heat, electricity and fuels, although representing a relatively low share of the economic value, accounts for the largest share (37%) of GHG emissions. Thus, IoB solutions and services aiming at energy optimization and increased efficiency have an excellent potential for successful climate change mitigation. The results indicate that the both economic and environmental value of IoB markets offer without doubt lucrative economic opportunities and motivation for digitalization as well as climate change mitigation.

**Keywords:** Internet of Buildings, real estate business, smart technology, climate change mitigation

# 1. Introduction

Digitalization offers substantial potential for private and public services across all sectors and is also widely considered as a cornerstone for international competitive edge in the future. Manyika et al. (2013) estimated that as few as twelve disruptive new technologies can have a potential economic impact of 14 to 33 trillion dollar per year in 2025 including only the technologies that we can anticipate today. Digitalization is also the cross-cutting theme of the current Finnish government's strategy in order to decrease the costs of public sector and increase the Finnish companies' potential in international markets (Finnish Ministry of Finance 2015). According to Kuusisto (2014), digitalization and smart services may be considered as a way to cut costs of current services and make them more efficient. Although consumer markets have been in the leading edge of development, digitalization and smart services are very likely to significantly transform business-to-business context and public sector as well.

The digitalization has already been opening up new opportunities within various sectors. Neirotti & Paolucci (2007) studied the strategic value of IT in Italian insurance sector and found out that the most firms on the sector increased their productivity through utilization of IT. Gastaldi & Corso (2012) analyzed the possibilities of digitalization in health care, specifically within hospitals and suggested criteria for successful digitalization process. Balta-Ozkan et al. (2013) stated that smart technology such as smart grids and smart meters have existed as concepts already in the past, but recent policies and objectives mandating energy efficiency and climate change mitigation significantly increased attention towards them over the last decade. Additionally, advancements in communication technologies and wireless devices have driven recent developments. In construction and real estate sector, the digitalization has been mainly focused towards building information models (BIM) and smart buildings with Internet of Things (IoT) – solutions. BIM is a computer-generated 3D model, which includes the relevant data to support the construction process (Eastman et al. 2011). According to Manyika et al. (2013) IoT refers to using sensors, actuators and data communication technology built into physical objects enabling the tracking, coordinating and controlling those devices across data network or Internet. These devices have recently spread from industrial use to consumer market, where people can monitor and control multiple numbers of private assets using apps on nowadays conventional smart devices (Rosemann 2013). However, currently most research concentrates on technological and within building activities. Hardly any studies have investigated the benefits of connecting users, service providers and buildings together and thus enabling more efficient solutions managing resource and service flows with a network of buildings.

In this paper, Internet of Buildings (IoB) framework is presented for the first time. We define IoB as an "ecosystem of buildings, users and service providers using smart buildings as an enabling technology". A smart home as defined by Balta-Ozkan et al. (2013) is "a residence equipped with a high-tech network, linking sensors and domestic devices, appliances, and features that can be remotely monitored, accessed or controlled, and provide services that respond to the needs of its inhabitants". The smart building technology serves as a technical platform for the IoB ecosystem where service providers can utilize digital solutions in transforming their business more resource efficient as well as generating new business opportunities. Even more importantly, users of

buildings currently in a role of consumers can activate as service providers as well and start producing value for the ecosystem using smart buildings as a platform. IoB-framework is connected to several earlier themes in academia including smart buildings, resource efficiency via digitalization, growing demand for consumer-oriented and on-demand services and GHG assessments and climate change mitigation in the built environment.

This study provides an insight into the potential market size of suggested IoB ecosystem by presenting the economic value of current public and private consumption of IoB in Finnish economy. A consumption based LCA was selected in order to evaluate the monetary value and GHG emissions of the potential IoB-industry on residential sector. The consumption approach enable us to evaluate building as service, i.e. the value of buildings is delivered to users during the extensive time of using the physical building instead of a single transaction. Thus, users have very a critical role in ecosystems of real estate sector, and setting the scope of the research into the consumer-oriented value generation is a relevant approach to study the value and GHG emissions in digitalized real estate business.

The paper is structured in four chapters. Chapter two describes the research materials and methods and processes of data analysis. Chapter three presents the results of the study. Finally the conclusions and implications of the study are discussed in the fourth chapter.

## **2. Materials and methods**

### **2.1 Research materials**

The main research material is the Statistics Finland's Household Budget Survey 2012 (Statistics Finland 2012a) and additional data on public welfare services including education, healthcare and social services (Statistics Finland 2012b). The Household Budget Survey includes detailed data on the expenditure of around 3500 Finnish households. The expenditure is divided into consumption categories according to the international COICOP-division (Classification of Individual Consumption According to Purpose, UN 2016). The data includes weight coefficients that correct the sample to represent the overall population of Finland. The weights are used in this study.

### **2.2 Research frame**

The purpose of the study is first to define the concept of IoB, and second to provide a view to the current monetary value and GHG emissions of the consumption-based economic sectors related to IoB. The purpose of quantifying the current expenditure on IoB related sectors, and the following GHG implications, is to give insights for the parties interested in developing IoB solutions and services. A consumption-based approach was chosen, since it is meaningful within the context of IoB to take the perspective of the end-user, who in the residential sector is the resident of the building. The end-users are expected to take part to the value creation in IoB.

The selection of the consumption categories that are potentially part of IoB is based on literature references discussing smart houses and smart grid. Based on the literature framework was made with selection categories presented below and in Table 1.

*Housing sector* is considered the core of residential IoB. Especially the housing energy and maintenance have a high potential for new IoB solutions and services (Fang et al. 2012, Dimeas et al. 2014, Vermesan & Friess 2014).

*Energy sector* is an essential part of IoB. For example, smart grid, distributed renewable power generation and electric vehicles as flexible electric power storages, users and suppliers, are expected to play an important role in energy use optimization (Lund & Kempton 2008, Fang et al. 2012, Richardson 2013, Erdinc 2014).

*Smart home applications* are enabling IoB solutions and services. They can be divided into applications that aim to the energy optimization, for example by controlling the energy use of home equipment and other electronic devices (Dimeas et al. 2014), and other applications, such as *security* and *entertainment services* and *eHealth* (Robles et al. 2010, Balta-Ozkan et al. 2013, Vermesan & Friess 2014, Zhang et al. 2015). For example, eHealth can shift health services from health centres to homes (Rialle et al. 2002, Baker et al. 2007).

In addition to being potential sectors for new *eServices* and smart home applications, some services are included in the framework since *service spaces* as such are part of IoB, similarly as residential buildings. For example, the energy optimization solutions can be used similarly in service spaces as in residential buildings.

As one can see, some consumption categories are considered more essential parts of IoB, whereas the connection of others is looser. However, the framework is purposefully made as comprehensive as possible. It can be restricted for later purposes, if useful.

Table 1. Selection criteria and the selected consumption categories

	Selected consumption categories	Selection criteria			
		Housing sector	Energy (smart grid)	Smart home	eServices and/or service spaces
Consumers:	Housing energy	x	x	x	
	Housing maintenance	x		x	
	Rentals and imputed rentals without energy and maintenance	x		x	
	Motor fuels		x		
	Personal vehicles and services		x	x	
	Public transport		x		
	Home equipment (white goods)			x	
	Housing related and social services	x		x	x
	Telecommunications		x	x	
	Entertainment electronics			x (lifestyle)	
	Health services			x (eHealth)	
	Cultural and leisure services				x (lifestyle)
	Insurances			x (Security)	
Public sector:	Education				x
	Health services			x (eHealth)	x
	Social services				x

## 2.3 EE IO analysis and hybrid life cycle assessment

The assessment of the monetary value and GHG emissions of IoB related sectors is based on an environmentally extended input output (EE IO) model (Leontief 1970). The EE IO models are based on input-output economics. Input-output tables of an economy consist of matrixes presenting the monetary transactions between economic sectors. Each sector uses inputs to produce outputs that are inputs to some other sectors (intermediate products), or end products or services for consumers. In the environmentally extended version environmental indicators, for example GHG emissions, are added to the matrixes to assess the cumulative environmental impacts (Leontief 1970).

A consumption-based EE IO model provides the total expenditure on each consumption category within an economy, and the respective cumulative environmental impacts. The consumption categories cover all consumption. The cumulative environmental impacts are assessed so that they include all the impacts caused during the life cycle of goods and services (cradle-to-gate) (Wiedmann 2009). The main strength of the method is the comprehensiveness. Truncation errors from system boundary selection are avoided, since the method is systemic and top-down type (Suh et al. 2004). However, the EE IO models are rather aggregate, depending on the aggregation of the consumption categories. The EE IO models can be improved by integrating more accurate process-LCA data to the model. Models combining EE IO analysis and process LCA are called the hybrid LCA models (Suh et al. 2004).

In this study, the GHG emissions from the selected consumption categories are assessed with the EE IO model of Finnish economy, called ENVIMAT (Seppälä et al. 2009). The ENVIMAT model provides GHG intensities (CO<sub>2</sub>-eq kg/€) for 52 consumption categories in Finland. In addition, a hybrid LCA model is used to assess the emissions from housing energy, motor fuels and personal vehicles more accurately. In the hybrid-LCA model, the coefficients of the combustion phase CO<sub>2</sub>-emissions from the energy production are 209 CO<sub>2</sub>-eq/MWh for district heating and 223 CO<sub>2</sub>-eq/MWh for electricity (Motiva 2012). The upper-tier emissions from fuel production and distribution etc. are provided by the ENVIMAT model. The heat and electricity price differences between different housing types are taken into account in the assessment. Also, the emissions from housing construction are assessed separately by using a living space -based estimate derived from Ristimäki et al. (2013). The used estimate has been calculated with the production version of the ENVIMAT model, using the production-side prices of goods and services. The estimate is 1.1 CO<sub>2</sub>-eq t/m<sup>2</sup>. The GHG assessment method of the study is described in more detail in Ottelin et al. (2015). The model is rather detailed, since it is used for broad research purposes.

It should be noted that the expenditure on rentals and imputed rentals are not used in the assessment of the GHG emissions to avoid double counting. The emissions from housing energy and maintenance are assessed separately with the hybrid-LCA model using household expenditure data and data on average expenses of housing companies in Finland (Statistics Finland 2016). Thus, the only emissions allocated to the sector of rentals and imputed rentals are the emissions from housing construction. The other emissions caused by expenditure on this category are considered low, and excluded from the assessment.

### 3. Results

The total monetary value of the IoB related market in 2012 in Finland was €70 000 million. The share of heating, electricity and motor fuels was €8 400 million. Housing (without energy) accounted for €1 300 million and personal vehicles €9 800 million. The share of other IoB related consumer goods and services was €14 400 million euros. Finally, public sector with education, health services and social services accounted for €16 500 million. The consumption volumes and following GHG emissions of IoB related consumption categories are presented in detail in Table 2 (The GHG emissions include only the emissions from housing construction. The emissions from housing energy and maintenance are in the respective categories. The additional emissions caused by rentals and imputed rentals are not included, but are considered low). The table shows also the GHG assessment method for each consumption category. Figure 1 illustrates the share of IoB related consumption and GHG emissions of the total consumption and GHG emissions in Finland at an aggregated category level.



Table 2. The total monetary value and attached GHG emissions of IoB related consumption in Finland

	Consumption category	€1000 million	CO <sub>2</sub> -eq Mt	GHG assessment method
Housing energy and motor fuels	Housing energy	4,7	12,3	hybrid-LCA
	Motor fuels	3,6	6,7	hybrid-LCA
Housing other	Housing maintenance	4,7	2,5	EE IO
	Rentals and imputed rentals without energy and maintenance	16,6	3,8	production-side EE IO
Personal vehicles and services	Personal vehicles and services	9,8	3,2	hybrid-LCA
Other IoB related consumer goods and services	Public transport	1,1	0,6	EE IO
	Home equipments (white goods)	1,4	0,6	EE IO
	Housing related and social services	1,1	0,2	EE IO
	Telecommunications	2,3	0,6	EE IO
	Entertainment electronics	1,4	1,1	EE IO
	Health services	1,1	0,2	EE IO
	Cultural and leisure services	3,7	0,6	EE IO
	Insurances	2,1	0,3	EE IO
Public welfare services	Education	7,9	2,4	EE IO
	Health services	6,7	1,3	EE IO
	Social services	1,9	0,4	EE IO

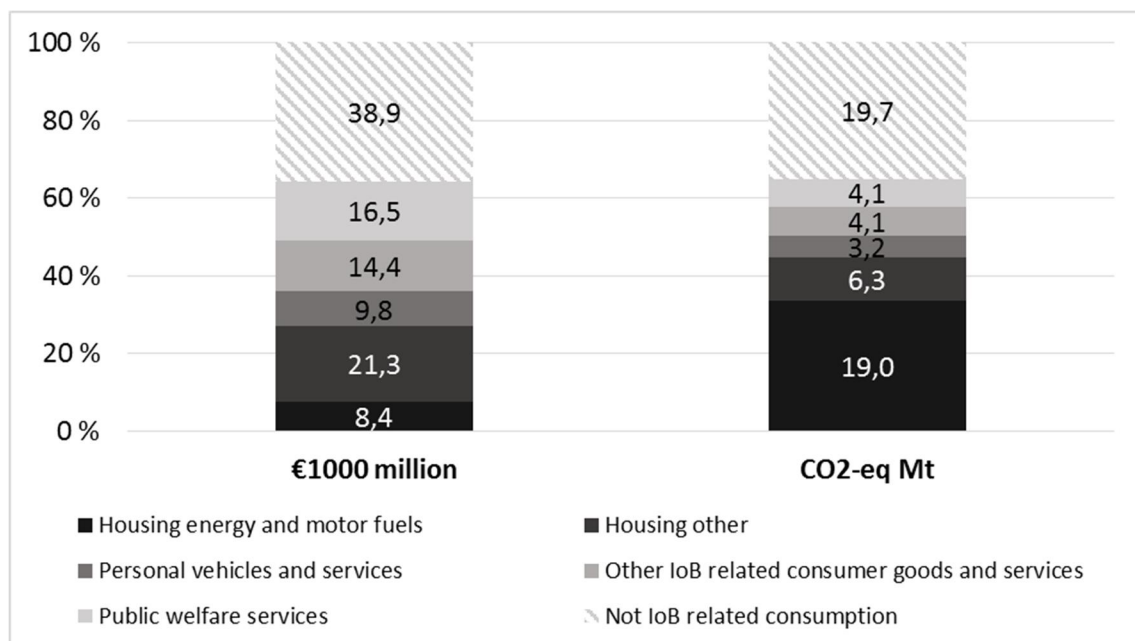


Figure 1. The share of IoB related sectors of the total consumption and GHG emissions in Finland

The results of the GHG emissions assessment indicate that housing energy's and motor fuels' relatively small shares of total monetary consumption result in very significant share of the total GHG emissions. The total GHG emissions from housing energy and motor fuels together are 19 Mt CO<sub>2</sub>-eq. Since the total consumption-based GHG emissions in Finland are 52 Mt CO<sub>2</sub>-eq, housing energy and fuels account for 37% of these.

## 4. Discussion and conclusions

The purpose of the study was to provide insight into a new concept called Internet of Buildings, in which digitalization enabled networking of buildings and real estate stakeholders will provide improved resource efficiency along with new business opportunities for real estate and construction sector.

The main contribution of the study is the presentation of the IoB concept and the assessment of the market value and GHG emissions of the current IoB related consumption in Finnish residential real estate sector. The total market value of IoB related activities is estimated to be €70 000 million, which means that currently consumers and public sector use more than half of their budgets on products and services that could potentially be a part of IoB. For comparison, the IoB related consumption is almost as significant as the combined turnovers of ICT (€45 000 million) and construction industries (€29 000 million) (FiCom ry, Statistics Finland 2016b).

It should be noted that some of the included consumption categories quite obviously belong to IoB, whereas the inclusion of some other categories is based on more far-reaching reasoning. Also, there may be consumption categories that are not included, but will become part of IoB, and more likely, consumption that does not exist yet, but will emerge, when the practical solutions of IoB develop. By improved knowledge of needs and behaviour of user and customer and by creating new innovative service packages based on the knowledge it would be possible to create an entirely new way to manage real estate.

In addition to the business potential, IoB carries also significant climate change mitigation potential. According to the assessment, the life cycle GHG emissions from housing energy and motor fuels consumption were 19 Mt CO<sub>2</sub>-eq in 2012, which accounts for 37 % of total consumption based emissions in Finland. Finnish energy production relies still heavily on fossil fuels, whereas wind and solar power and decentralized energy production are marginal. According to the Finnish Ministry of Employment and the Economy (2015) taking advantage of renewable energy is still in initial and planning phase, although several investment decisions of over €1 000 million have been made on wind and solar power as well as biofuel industries for the years 2016-2017. IoB, including smart grid and electric vehicles (EVs), would provide a possibility for much higher integration of renewables into the Finnish energy system.

Richardson (2013) concluded in his review on EVs and renewable energy that studies on this topic overall indicate that EVs have the potential to increase the amount of renewable energy, especially wind energy capacity installed in electricity systems. EVs can absorb and storage excess wind and solar energy that would otherwise be wasted. For example, Juul and Meibom

(2011) studied integration of electric power and transportation sectors in Denmark, and calculated 85 percent reduction in transportation related CO<sub>2</sub> emissions. Most of the studies concluded that especially high reductions can be achieved by using smart charging and vehicle to grid (V2G) capability. V2G means that EVs have the ability to store electricity and return it to the electric grid.

As one can imagine, EVs with smart charging and V2G capability fit well together with smart buildings and distributed energy generation such as solar panels and small wind turbines integrated to buildings (Fang et al. 2012). With two-way flows of electricity and information, buildings would be able to for example feed their excess electricity to the smart grid and avoid electricity consumption on peak times. Furthermore, smart building solutions already enable maintaining the optimal indoor conditions. Further energy savings have also been shown to be associated with remote energy management of buildings (Määttänen et al. 2014) and simply adjusting the settings of HVAC equipment in buildings and thus restoring and maintaining the original energy efficiency of buildings' technical equipment (Christersson et al. 2014). Thus, even the most conservative scenarios of IoB in the future reach significant reductions in energy consumption. In IoB, energy use is not optimized only within a building, but within a network of buildings. However, to support IoB, the electricity generation industry must transform into an information intensive service with capability to two-way flows of energy and information. Electricity as a product must become more consumer oriented with variability for different consumer needs.

There are some uncertainties in the study related to the initial data. First, all public consumption is not included in the assessment due to limitations in data availability. However, the public welfare services, included in the study, are perhaps the most relevant public sector considering IoB. They also constitute a significant share of the overall consumption in Finland, which gives a reason to include them in the assessment. There is a high potential for IoB solutions and services in this sector. However, the results involve higher uncertainty than the results on consumer goods and services. The data from the public sector is much more aggregate than the household expenditure data, and provided simply as an average expenditure on public education, healthcare and social services per capita in Finland.

Since information flows and big data will be the key factors for IoB business, the security issues related to the smart grid and IoT are equally important in IoB. All smart technologies must be combined with smart protection systems. Protection of IoB should be seen as a business opportunity and a competitive edge. IoB can only live up to expectations, if customers can trust its reliability, privacy and security. Bearing this in mind, we welcome the new digitalized era of the built environment.

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# Evaluation of Attributes for Healing spaces of Medical Ward

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## Abstract

The objective of this research is to examine the opinion of patients and visitors toward the environment of the medical ward of Maharaj Chiang Mai Hospital. The overall environment was assessed to identify the issues that have affected to the patients environmental adjustment. The adjustment is based on the idea of Healing Environment for improving health of both patients and visitors during their visit to the ward. Ten dimensions of surrounding and environmental factors that are evaluated using questionnaires consists of Lighting, Fresh air, Scent, Gardens and the outdoors, Interior environment, Quietness, Spatial layout, Comfortable atmosphere, Art and positive distractions and Colour. The study results which examined the evaluation from of the patients and the visitors of the medical ward was rated as poor. The comparison on the opinions of patients and visitors that are negatively affected by the environment suggests that the cause of the problem varies at significance level of 0.05, in which visitors evaluates environmental issues more highly than patients. These results will be analyzed and used for designing the healing environmental guidelines for the medical ward of Maharaj Chiang Mai Hospital.

**Keywords:** Attributes for Healing spaces, Patient and Visitors, Differences, Opinion

# 1. Introduction

The procedures that take environmental issues into account or healing environment plays a significant role in designing hospital at international level. However, this principle is relatively new and is very interesting for hospital architecture in Thailand.

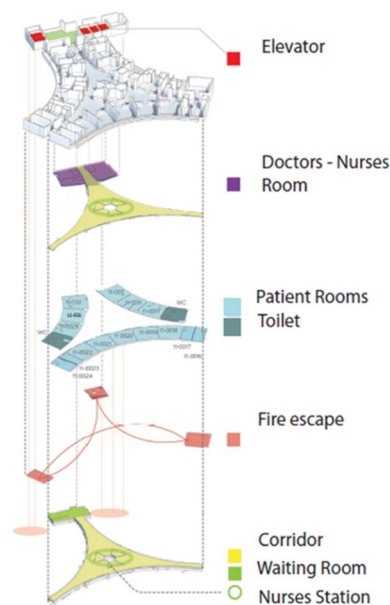
The main purposes of the study are as follow:

1. Presenting an evaluation of environmental issues in patient wards by evaluating the opinion of both patients and visitors whose opinions are valuable for improving hospital design.
2. Comparing the differences among the opinions of patients and visitors
3. Proposing tentative guidelines based on the principle of healing environment

## 2. Background and Signification

Maharaj ChiangMai Hospital, the largest hospital in the North of Thailand with 1,400 patient beds and is fully operated by Ministry of Public Health (Thailand) and providing all treatment to all patients. However, current wards in the hospital buildings are in state of disrepair. Therefore, the policy of improving the environment for health promotion, by taking the principle of healing environment into account, has been announced; the important condition that needs improvement will be in accordance with the opinions of the patients, visitors, and staff.

The medical ward is used as Pilot Project Area, according to the evaluation; the condition of this ward is the poorest in the hospital. Hence, it is necessary to improve the ward. This ward is located on 11th floor of Sujinno Building, the reinforced-concrete of 15 stories. Natural ventilation is used along with the installed fans. The plan of the building is in a y-shaped. The total area of the ward is 1350 square meters, in which the area of patients' rooms is 554 square meters and consists of 15 rooms and 85 beds.



*Figure 1: Medical Ward of Sujinno Building Functional Plan*





*Figure 2: Patient Rooms in Medical Ward of Sujinno Building*

The study begins by gathering research which is related to healing environment. The data is applied for creating evaluation form that will be distributed to both group of patients and visitors then who are the main users in Sujinno Building.

### **3. Literature review**

Attributes for Healing spaces one research done by F. C. Bloemberg's researches in 2009 in Healing Environments in Radiotherapy Recommendations regarding Healing Environments for Cancer Patients has showed research outcome which demonstrated 10 physical factors that are used for healing patients' health in accordance with the combination of the research in the same field. The mentioned factors are as follow:

1. Lighting: Artificial lighting have certain benefits, but certain characteristics have been argued to negatively affect mood and performance. The lighting should neither be too dim, nor too bright. Warm, indirect lighting is recommended. Lighting should not create sharp shadows; neither should it eliminate shadows completely. Providing lamps can also increase a homely feeling. (F.C. Bloemberg, 2009) Natural light in hospitals benefits effectively because it can improve psychological states for both patients and staff. (L.Edwards and P.Torcellini, 2002)

2. Fresh air: Fresh outdoor air is recommended, as this can influence temperature and humidity, whereas poorly ventilated buildings can affect uncomfortable symptoms of sickness. (F.C. Bloemberg, 2009) Poor ventilation in hospital is seen as the main cause of nosocomial disease. Providing pleasant and comfortable temperature that can be individually adjusted by patients in case of individual differences will support a sense of privacy. Install ventilation systems that widely generate fresh air and, again, can be adjusted for individual differences. Natural and mechanical ventilation systems are often preferred over air conditioning systems. Air-conditioning systems are to be preferred over natural ventilation only in certain circumstances, for instance, very hot climate, or rooms that require the highest standard of air quality for prevention of infections such as an OR or ICU. (Netherlands Board for Healthcare Institutions, 2008 pp.30-32) Comfortable zones of Thai people are in the ranges of relative humidity 50% - 70% and effective temperatures of 24°C - 27°C for air velocity 0.2 m/s. (Juntakan Taweekun, 2013)

3. Scent: Scent is perceived as positive as it can reduce anxiety, whereas negative scents stimulate stress and fear. Although food scents can be perceived as positive, they can make cancer patients feel nauseated. Aromatherapy can increase a sense of relaxation, does not decrease anxiety for cancer patients receiving radiotherapy.(F. C. Bloemberg 2009)

4. Gardens and the outdoors: People experience less stress when they have access to gardens. Elements such as trees, grass, water, visible sky, rocks, flowers and birds particularly provide this positive effect. Gardens in healthcare settings should not only ideally offer several different opportunities, but also offer both private as well as communal space. (F. C. Bloemberg 2009)

5. Interior environment: Patients who see the trees and water scenery are significantly less anxious during the postoperative period than patients who is assigned to see the other scenes and control conditions. Moreover, patients who are exposed to the trees and water scenery suffer less severe pain, because they shift faster than other groups from strong narcotic pain drugs to moderate strength analgesics.(Li.wang, 2011) To keep other factors constant for proper outcomes, the methods ensured that patients who see the trees and the wall are equivalent, in terms of age, weight, tobacco use, and general medical history. The result showed that those who see nature scenery, compared to those who look out at the wall, have shorter hospital stays and suffer fewer minor post-surgical complications.(Roger S, 2002)

6. Quietness: Loud noises can affect patients' health negatively. Therefore, reducing noise by using equipment and doors that create less noises is important. Sound-absorbing materials in the ceiling and on the walls contributes to this, although it might be harder for staff to hear when patients are calling for help. Certain sounds, like music, can have a positive effect on patients' anxiety levels and mood. Slow; smooth music without accented beats is preferred. As music can be disturbing as well, it is recommended to give patients freedoms to choose. (F. C. Bloemberg 2009) Eliminating and reducing noise sources, for instance, using soundless paging systems, wireless communication systems, switching off equipment that is not being used, and taking into account the noise level and the adjustability when purchasing the equipment. Also the realization of separate rooms for outpatients consultation, separation rooms from noisy zones, and the use of good logistics creates peace and quietness for patients and gives the staff the opportunity to focus on their duties. It is also important to train the staff to speak in a lower voice and aware of patients. The sound level of noise in hospital should not be more than 45 decibels (dB) during the day and 35 dB at night.(Netherlands Board for Healthcare Institutions, 2008)

7. Spatial layout: In the spatial layout of the hospital, it is crucial that people can find their way easily. Way-finding is important This can be achieved by making the building asymmetrical and using clear signs. A recognizable kind of way-finding is recommended, such as paths' names. Different waiting areas should be provided for in and outpatients. Thus, walking distances should be kept as short as possible.(F. C. Bloemberg 2009) Solutions to improve orientation are found in integrated systems by providing simple, clear and consistent sign-posting combined with written and verbal information. (Netherlands Board for Healthcare Institutions, 2008) Room privacy perception is also likely to play an important role in the patient's well-being, because privacy can lead to a positive perception of the room. Both the extent of visual access (quantity of view of the room) and the extent of visual exposure (the extent to which a person is visible to others) turn out to affect the privacy perception. (Ulrich, 1984)

8. Comfortable atmosphere: Seemingly sterile environments and making it feel more like home is advisable. However, this shouldn't be overdone as people expect a certain professional atmosphere in a hospital. Concealing technical equipment and clutter in cabinets and behind screens also contributes to a comfortable environment, as well as providing possibilities for children to play.(F. C. Bloemberg 2009)

9. Art and positive distractions: Works of art can improve the aesthetic appeal of a hospital and provide distraction. Other distractions, such as radio, television, internet and telephone, can also contribute to positive distraction.(F. C. Bloemberg 2009)

10. Colour: Most agree that it can decrease the institutional atmosphere of hospitals. In general it is recommended to use warm, soft, natural colours. Grey and dull shades should be avoided, as they can produce anxiety.(F. C. Bloemberg 2009) Natural colour creates healing atmosphere; the healthcare environment such as green is thought to be restful and healing, as it is the color that associated with balance, harmony and renewal. Blue has always been connected to calm. Room painted in natural shades could lower blood pressure and the heartbeat, and allows for deep breathing as it relaxes muscles and the mind. (Laura Guido-Clark Design, LLC, 2011)

The result of the study will be adopted for creating the questionnaire to evaluate the overall ward environmental issues.

## 4. METHODOLOGY

The research tools of this research are questionnaire, as it is survey research. The sample groups of this research are the patients and visitors of the medical ward in Maharaj Chiang Mai Hospital. At present the Medical Ward has 130 visitor and patients per day. Which can be classified by 55 visitor and 75 patients Therefore the researcher has divided the simple groups into 2 as followed.

1) 63 sample patients are selected by the nurse as physically and mentally strong to complete the questionnaire and the patients have been treated in hospital for more than 5 day

2) 48 visitors who come in to visit the patient ward in the morning form 12:00 PM – 1:30 AM and 3:00 AM – 7:00 AM in the afternoon.

The simple population (size) is adapted from Krejcie & Morgan, 1970 which 95% validity.

The questionnaire, which is designed from the literature review, contains 36 closed-ended questions using Likert Scale for measurements. Every question is focused on negative-sense items that can be described as follows: (Table 1-2)

*Table 1: Rating Scale for Questionnaire*

Patients and Visitor Perspective	Scores	Rating	Description
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Agree	3	3.00-2.33	Poor
Neither agree nor Disagree	2	2.32-1.67	Fair
Disagree	1	1.66-1.00	Good

This rating scores are used to measures the manner the environmental issues within the medical ward Maharaj hospital. Table 2 describes important aspects of environmental issues in the hospital building.

*Table 2: Important environmental aspects for evaluation*

Environmental Issues	
No.	A. Lighting
1	Disturbance from the bulbs(Day lighting)
2	Disturbing colour because of light(Day lighting)
3	Insufficient natural light(Day lighting)
4	Insufficient light in the patient's room(Day lighting)
5	Excessive light in the patient's room(Day lighting)
6	Disturbance from the bulbs(lightning night)
7	Disturbing colour of light(lightning night)
8	Insufficient light in the patient's room(lightning night)
9	Excessive light in the patient's room(lightning night)
	B. Fresh air
10	Insufficient air ventilation
11	Hot diurnal temperature
12	Hot nocturnal temperature
	C. Scent
13	Disturbance from food scent
14	Disturbance from chemicals/medical substances
15	Disturbance from outside
	D. Gardens and the outdoors
16	The lack of green area
17	The lack of outdoor area for leisure
	E. Interior environment
18	Small window that is not suitable for sightseeing
19	The unpleasant scenery from the window
20	The lack of combining nature with the interior design of patient's room

*Table 2: Important environmental aspects for evaluation*

No.	F. Quietness
21	The noises from the staff
22	The noises from the conversation of the visitors

23	Noises from outside
Environmental Issues	
G. Spatial layout	
24	Crowded resting area
25	Distant medical counter from the patient's room
26	Unorganized items
27	The lack of privacy of patient's room
28	Crowded patient's room
29	No clear signs for telling paths
H. Comfortable atmosphere	
30	Unmitigated atmosphere in the medical ward
31	Improper bed that causes stiffness
32	Improper chair that causes stiffness
33	Declined floor, wall and ceiling
34	The lack of convenient items like TV, book, and magazine
I. Art and positive distractions	
35	The lack of using artworks for interior design
J. Colour	
36	The colours inside the building that cause depression
37	overall environment

The questionnaire is evaluated by using the Cronbach's Alpha Coefficient from 50 samples of the customers before being used for researching. The ratings of the questionnaire is 0.85, which means this questionnaire is reliable (more than 0.8)

## 5. Results and Discussions

The result of comparison on the evaluation of environmental issues from patients and visitors using t-test for Independent is as followed. (Table 3)

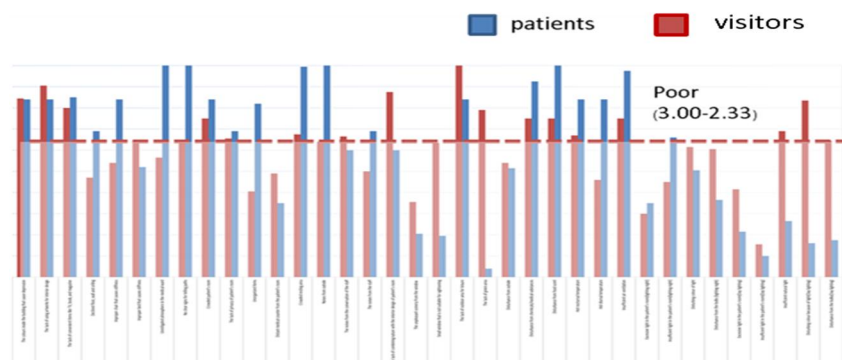


Figure3: Poor level environmental issues

Table 3: Results of t-test Independent for opinion differences among the patients and visitors

No.	Environmental Issues	Patients			t-test		Visitors		
		S.D.	mean	Criteria	t	p	Criteria	mean	S.D.
A.	A. Lighting								
1	Disturbance from the bulbs	0.48	1.35	Good	-10.7	.00*	Fair	2.29	0.46

	(Day lighting)								
2	Disturbing colour because of light (Day lighting)	0.47	1.32	Good	-15.3	.00*	Poor	2.67	0.48
3	Insufficient natural light (Day lighting)	0.56	1.53	Good	-6.48	.00*	Poor	2.38	0.79
4	Insufficient light in the patient's room(Day lighting)	0.44	1.2	Good	-1.3	0.19	Good	1.31	0.47
5	Excessive light in the patient's room(Day lighting)	0.60	1.43	Good	-2.51	.01*	Fair	1.83	1.00
6	Disturbance from the bulbs (lighting night)	0.96	1.73	Fair	-3.7	.00*	Fair	2.21	0.46
7	Disturbing colour of light(lighting night)	0.12	2.01	Fair	-3.45	.00*	Fair	2.23	0.43
8	Insufficient light in the patient's room(lighting night)	0.50	2.32	Fair	3.3	.00*	Fair	1.9	0.81
9	Excessive light in the patient's room(lighting night)	0.96	1.7	Fair	0.59	0.55	Good	1.6	0.87
B.	B. Fresh air								
10	Insufficient air ventilation	0.33	2.95	Poor	4.59	.00*	Poor	2.5	0.62
11	Hot diurnal temperature	0.47	2.68	Poor	5.53	.00*	Fair	1.92	0.87
12	Hot nocturnal temperature	0.47	2.68	Poor	3.79	.00*	Poor	2.34	0.48
C.	C. Scent								
13	Disturbance from food scent	0.00	3	Poor	5.59	.00*	Poor	2.5	0.62
14	Disturbance from chemicals/medical substances	0.36	2.85	Poor	3.56	.00*	Poor	2.5	0.62
15	Disturbance from outside	1.00	2.03	Fair	-0.3	0.76	Fair	2.08	1.00
D.	D. Gardens and the outdoors								
16	The lack of green area	0.40	1.08	Good	-11.8	.00*	Poor	2.58	0.82
17	The lack of outdoor area for leisure	0.47	2.68	Poor	-5.92	.00*	Poor	3	0.00
E	E. Interior environment								
18	Small window that is not suitable for sightseeing	0.54	1.39	Good	-8.3	.00*	Fair	2.27	0.61
19	The unpleasant scenery from the window	0.81	1.41	Good	-1.8	.07	Fair	1.71	0.97
20	The lack of combining nature with the interior design of patient's room	0.91	2.2	Fair	-4.45	.00*	Poor	2.75	0.44
F.	F. Quietness								
21	The noises from the staff	0.91	2.38	Poor	2.74	.00*	Fair	2	0.75
22	The noises from the conversation of the visitors	0.00	2.2	Fair	-1.04	0.3	Poor	2.33	0.48
23	Noises from outside	0.12	3	Poor	10.6	.00*	Fair	2.28	0.46
G.	G. Spatial layout								
24	Crowded resting area	0.12	2.99	Poor	8.2	.00*	Poor	2.35	0.53
25	Distant medical counter from the patient's room	0.96	1.7	Fair	-1.62	0.1	Fair	1.98	0.89
26	Unorganized items	0.49	2.64	Poor	5.85	.00*	Fair	1.81	0.89
27	The lack of privacy of patient's room	0.49	2.38	Poor	0.67	0.5	Fair	2.31	0.59
28	Crowded patient's room	0.47	2.68	Poor	1.67	.09	Poor	2.5	0.62
29	No clear signs for telling paths	0.00	3	Poor	8.8	.00*	Fair	2.27	0.57
H.	H. Comfortable atmosphere								
30	Unmitigated atmosphere in the medical ward	0.00	3	Poor	6.05	.00*	Fair	2.13	1.00
31	Improper bed that causes stiffness	0.20	2.04	Fair	-2.88	.00*	Fair	2.29	0.58
32	Improper chair that causes stiffness	0.47	2.68	Poor	6.94	.00*	Fair	2.08	0.45
33	Declined floor, wall and ceiling	0.49	2.38	Poor	3.31	.00*	Fair	1.94	0.84

*Table 3: Results of t-test Independent for opinion differences among the patients and visitors*

34	The lack of convenient items like TV, book, and magazine	0.59	2.7	Poor	0.87	0.38	Poor	2.6	0.64
I.	I. Art and positive distractions								
35	The lack of using artworks for interior design	0.47	2.68	Poor	-1.73	0.08	Poor	2.81	0.39

J.	J. Colour								
36	The colours inside the building that cause depression	0.47	2.68	Poor	-0.12	0.9	Poor	2.69	0.59
37	Overall environment	0.74	2.34	Poor	-0.26	0.79	Poor	2.38	0.76
* significant at 0.05 level.									

The result suggests that the condition of the environment, as evaluated by patients and visitors, is poor (score 2.36). The patient group evaluation results show that there are nineteen aspects that fall into poor evaluation level which include: insufficient air ventilation, hot diurnal temperature, hot nocturnal temperature, disturbance from food scent, disturbance from chemicals/medical substances, the lack of outdoor area for leisure, the noises from the visitors, noises from outside, crowded resting area, distant medical counter from the patient's room, unorganized items, the lack of privacy of patient's room, the lack of clear signs for telling paths, unmitigated atmosphere in the medical ward, improper chair that causes stiffness declined floor, wall and ceiling, the lack of convenient items like TV, book, and magazine, the lack of using artworks in interior decoration, the colours inside the building can cause depression.

While there are fifteen issues that are evaluated as poor by the visitors which included: disturbing colour of light(day lighting), insufficient natural light(day lighting), insufficient air ventilation, disturbance from food scent, disturbance from chemicals/medical substances, disturbance from outside, the lack of green area, the lack of outdoor area for leisure, the lack of combining nature with the interior design of patient's room, the noises from the conversation of the staff, crowded resting area, crowded patient's room, the lack of convenient items like TV, book, and magazine, the lack of using artworks for interior decoration, and the colours inside the building can cause depression.

The comparison on the evaluation of environmental issues from patients and visitors varies at significance level of 0.05 with 11 exceptional issues which are insufficient light in the patient's room, excessive light in the patient's room, disturbance from outside, The unpleasant scenery from the window, the noises from the conversation of the staff, distant medical counter from the patient's room, the lack of privacy of patient's room, the lack of convenient items like TV, book, and magazine, the lack of using artworks for interior decoration, crowded patient's room, and the interiors colours can cause depression. There is no significant differences of opinions on these 11 issues.

## 6. Conclusion

The improvement of environment in the medical ward has improved to a certain level that satisfies the customers. There should be the consideration of the different comments from both sides, as the result of the study shows that the majority of users, both patients and visitors, have different views in many aspects. The environmental adjustment in the building can be completed by dividing the analysis and the adjustment according to main users' preferences. For example, in order to improve the environment of patients' rooms, the opinions of the patients should be the main concern, as the majority of the area users is patients. On the other hand, visitors only spend one to five hours a day for the visit. If the evaluation from the main users has been analyzed for finding the average value, the result of evaluation might be incorrect and the improvements cannot satisfy both patients and visitors.

### 6.1 Proposing tentative guidelines based on the principle of healing environment



From the study the researcher found out difference opinion between both user of patients and visitors the first difference is the lighting colour that do not case the relax anion feeling (Day lighting no.2) Which the patients evaluated as good but the visitors evaluated it as poor. This study showed that the word uses day light from fluorescent lamp.

As from the in depth interview of 10 patients, they all preferred the day light that is presently used in the ward due to the clarity of vision and most patients said they also use it at their residence . This was opposed by the visitor's opinion, they evaluated it as poor which was supported by 7 in depth interview of the visitors. They claimed the day light gives old and dull feeling and it has made the ward, the office and the operation room unrelated and seemed old. One of the visitors has suggested using warm tone lighting in the hospital to promote the feeling as if they are in a hotel or resort that promotes relaxation.



*Figure 4: Fluorescent lighting and Natural lighting in the building*

The second difference of Insufficient natural light (Day lighting no.3), the patients have evaluated it as good on the other have the visitors gave it a poor, from the study, the lighting of the patients word have high intensity from the window from 6am-6pm at 512.13 lux. Also in depth interview of 10 simple patients showed the positive feeling towards the natural lighting. Some performed the natural lighting from the beds in control, the visitors' comments were unfavourable, they said that natural light am disturbed the patient and it gives a humid feeling

The above information obviously showed that patients opinion as the resident who are cared for in the ward for average of 5-7 day is opposed to the visitors as a guest who come to the visitors who come to the building for 1-3 hours per day.

It is cleared that the patients as the resident experienced the ward living more than the visitors. So there are different in evaluated and scale rating the real exposure to hospital ward of patients can be varied from the visitor. In the near future of hospital environmental design show include the user expectance into the design due to the real experience by patients might be difference from the visitors They sped only 1-3hr/day on this information is adopted to be use in hospital design the hospital will be able to serve the real needs of all parties 62 further suggestions

#### 6.2 Future of suggestion

This research is the pilot study and the initiative for development of design theory for Thai hospital, We need to consider south east Asia demographic, geography, animate and social regions. These elements were distanced from the western design who claimed that colour of lighting can create the wearing feeling. however, the patients in this study has recommended and



preferred the day light to warm lighting the warm lighting theory claimed that it can create the relation better than day light this proved that the users behaviour in each regions and geographies area have distinctive preference so, The researcher would like to suggest for further investigation of demographic area, geography, climate, social, religion and tradition into implementation with evidence – based design for South East Asia hospital.

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# The Workplace for Researchers – Enhancing Concentration and Face-to-face Interaction

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## Abstract

It has traditionally been assumed that academic research is lonely work by its nature, including concentration, privacy and an “ivory tower” kind of work environment. However co-operation, communication and interaction are important parts of the research processes too. Academic workplaces need to support new ways of working, which requires effective support for both interactive and individual work. In this paper we discuss about academic research work and its requirements. More precisely the goal is to investigate the workplace requirements of academic workplaces for researchers: What is required from workplaces that support both concentration and face-to-face interaction and are there any differences between generations in regard to this?

The empirical data for analysis was gathered by a national survey conducted in Finland. The number of responses from researchers was 1 020. The response rate in the survey was 10%. The sample was linearized to match the demography of researcher population. It was assumed that the low response rate would not cause bias to the difference between different age group for respondents compared to non-respondents. Open-ended questions about the research environment accumulated answers, which were analysed and clustered. Three categories identified were demand for workplaces supporting: concentration, face-to-face interaction or both. Deeper analysis was conducted by analysing answers to the third category (workplaces that support both concentration and face-to-face interaction) in the age groups  $\leq 30$  years old and  $> 50$  years old. The analysis indicates that the older generation requires spaces that support both formal and informal interaction with internal and external partners, interdisciplinary and international interaction. The younger generation mainly prefers spaces in which to concentrate on one's work and to interact with one's research group.

The weakness of this study is the generalizability of the result to other cultures, since this survey was conducted in Finland. Some concern also arises since the response rate was low. The practical implications from this study reveal several topics worthy of future study. The multigenerational academic workplace can be investigated more thoroughly from both the perspectives of the design and use of the workspaces.

**Keywords:** academic, workplace, face-to-face interaction, concentration, generations

# 1. Introduction

Fostering collaborative partnerships in scientific research has emerged as a critical imperative for academic researchers. However the traditional research setting is connected to isolation and concentration – to the “ivory tower” of researchers. The increasing volume and accelerating pace of knowledge creation has transformed the research process to the point where one needs to redefine the requirements of physical workplace solutions in academic workplaces.

This paper aims to identify the social and spatial requirements for academic workplaces for researchers in universities – how academic research work is supported by diverse spatial and social solutions in office spaces. More precisely the goal is to describe what is required from workplaces for them to support both concentration and face-to-face interaction and to discover whether any differences in requirements exist between generations.

The literature review presents previous research about places for knowledge creation and requirements for academic workplaces. The method and data analysis section describes how the research data was gathered and analysed. The final section – the results and discussion – presents the findings.

## 2. Literature review: Academic workplaces

Academic research creates new knowledge. Knowledge is created through interactions amongst individuals or between individuals and their environments, rather than by an individual operating alone (Nonaka et al., 2001). Seeing the knowledge creation process as a spiral model – where tacit and explicit knowledge are in continuous interaction – was first described by Nonaka and Takeuchi (1995). The single most important factor shaping the quality of knowledge is the quality of place (Nonaka et al., 2001). Agnew (1987) defined the fundamental aspects of place as a “meaningful location, which has a location, locale and a sense of place.”

The workplace has a role in each step of the process of knowledge creation and the requirements towards workplace’s nature and characteristics differ accordingly. The demands for the nature of the workplace are presented in a classification system developed by Nenonen (2005). The physical, social and virtual work environments are the matters of interest.

**The connective place** is an environment that supports the exchange of tacit knowledge in the socialisation phase of knowledge creation. It is an interactive, open and cosy place with limitless information, which belongs to users. **The structural place** is an environment that supports the conversion of the tacit knowledge into the explicit knowledge; the externalisation phase of the knowledge creation process. The dynamic atmosphere of the place might be conservative and dedicated to task performance, like that of a formal meeting room. The virtual workplace serves as a facilitator; it is a technical source of information. **The formal place** is an environment that supports the analysis of explicit knowledge in the combination phase of knowledge creation. This place is more for individual and private work performances. The place supports the role of one

individual, offering privacy and supporting concentration. The virtual workplace is dedicated to information. **The reflective place** is an environment that supports the sharing of explicit knowledge and transforming it into tacit knowledge in the internalisation phase of knowledge creation. The place supports the sharing of knowledge and creation of innovations. Internal privacy is respected. The place empowers reflection and relaxation. The virtual workplace facilitates the sharing of information and the transformation of it into new knowledge (Nenonen, 2005).

Harrison and Cairns (2008) presented office types developed to support academic work:

- **Studies:** Small private offices to support individual work and private meetings with lounge areas for more informal discussion.
- **Quarters:** Small private familial workspace for around four to seven people. These environments can support the building of relationships and provide both companionship and privacy.
- **Clusters:** Group-centred workspaces for clusters of staff with common interests or identities. This environment can support collaborative work on various scales. Workspaces are semi-open, flexible spaces for teams of six to twelve people.
- **Hubs:** Hub workspaces are larger open plan work environments to support teamwork, mentoring and awareness of others. Visibility and connectivity are key.
- **Clubs:** Clubs provide a non-territorial workspace in which to connect with colleagues and peers while working autonomously, enabled by mobile technology and working practices.

Studies and quarters are work environments that are protected from the external world and can be considered to support the requirements of a formal place. Clusters can be considered reflective places. Hubs and clubs are more open to the external world and can be considered connective places. The physical form of an office does not dictate the nature of it, since the form only shapes part of the atmosphere. Many of the office types can contain several of the elements required for each stage of knowledge creation.

In many regards, the traditional cellular office, with its formal nature, may be considered the ideal academic work environment. It allows its occupant to switch between activities that require quiet concentration and reflection, such as preparing lecture notes and writing papers, and noise generating activities, such as telephone conference calls, meetings and collaborative work (Pinder et al., 2009). For an academic, work on a task that requires concentration, such as writing a paper, is likely to take place over a number of days or even weeks and likely to be interspersed with work on other tasks. Any structuring that the academic has imposed on their work environment in relation to the task (i.e. piles of paper and so on) may, if left in place, facilitate its later resumption – in effect allowing them to “dip in and out” of the task more easily (Kirsh, 2001; Malone, 1983).

Harrison and Cairns (2008) conducted a survey on employees across seven academic institutions. Their results indicate that the staff generally considered that the most important quality of the work environment is that it is “a place in which you can concentrate on your work”. The second

most important feature of a workplace was it being “a place that supports quiet reflection and analysis”.

Individual face-to-face interaction is the only way to capture the full range of physical senses and psycho-emotional reactions (such as ease or discomfort) that are important elements in sharing tacit knowledge (Nonaka et al., 2001). Face-to-face interaction makes it possible for two people to send and receive messages simultaneously and to exchange both the verbal and nonverbal messages that result in shared meanings. Lansdale et al. (2011) studied interaction in research environments and defined face-to-face interaction to be two or more people engaging in reciprocal exchanges. Haynes (2008) studied office productivity, interaction and distraction. Interaction was found to be beneficial and distraction was reported to be negative. Heerwagen et al. (2004) state that face-to-face interaction is the most common form of interaction and communication in a variety of work settings. According to study by Melin (2000), increased knowledge, higher scientific quality and the generation of new ideas were the main benefits generated from collaboration. Although collaboration is defined as “working together”, effective collaboration entails both individual focused tasks and interactive group work (Heerwagen et al., 2004). According to a study by Lee and Bozeman (2005), more than half (51.1%) of research time is spent with colleagues in the immediate work group, with the next largest amount of time (15.9%) being devoted to working alone.

Finding the right balance and types of support for individual and group work requires an understanding of both social and cognitive processes (Heerwagen et al., 2004). Danielsson and Bodin (2008), and Been and Beijer (2014) have compared different office types and their capacity to support concentration and interaction. It would seem that one particularly effective solution to the quiet/interaction dilemma is the combi-office where each academic has their own small study, located off a shared open space that includes an array of breakout areas and additional storage, as well as a kitchen, a printer hub and a number of bookable meeting rooms (Pinder et al., 2009).

The Activity Based Working approach is regarded as one of the most advanced concepts (Ross 2010). It is supported by work environments that combine hot-desking with a variety of workplaces designed to support different types of activities (Hoendervanger, 2015). Appel-Meulenbroek et al. (2015) describes that the employees who work in activity based working environment are more satisfied with seclusion rooms, climate, décor, cleanliness and leisure compared to ones in traditional work environments.

Rothe et al. (2012) studied the differences between age groups in their workplace preferences. Younger groups preferred work environments that support teamwork, social interaction and innovation within the organization. Older groups preferred more networking possibilities with other interest groups within the building. The virtual environment and mobility are, in general, valued more among the younger respondents while personal services and being able to adjust the indoor climate are more important to the older groups. The smallest differences were found concerning privacy (Rothe et al., 2012).

Lee and Bozeman (2005) studied the differences between age groups in academic settings. It seems reasonable to expect that collaboration would be a different experience for tenured older faculty and research group leaders than for untenured young faculty, postdoctoral researchers or graduate students. A collaboration that is quite productive for an experienced young researcher may prove “inefficient” for the mentor (Lee and Bozeman, 2005). Pinder et al. (2009) point out that the starting point of an academic career – doctoral research – is largely a solitary activity and an individual achievement.

Pinder et al. (2009) argue that if efforts to reduce occupancy costs by ten percent result in even a one percent reduction in the income-generating potential of an academic (through lost productivity and motivation), then the benefits of the space efficiencies will be lost (Pinder et al., 2009). This underlines the importance of understanding the consequences each design solution has on productivity. To conclude the existing literature and research overview one can state that the discussion about both academic and office environments is connected to the diversity of workplace solutions as well as to the different ways of using the workplace. There is an increasing emphasis on supporting both individual and collaborative work processes. In the next chapters the emphasis is on increasing understanding of the demand for supporting both the concentration and face-to-face interaction that researchers are presumed to require from office premises. A research gap for research on the academic knowledge workplaces of different generations can be found. Is a formal or informal environment better for face-to-face interaction? Do researchers prefer internal interaction with their team or do they yearn for interaction with external partners, interdisciplinary interaction or international interaction. Is face-to-face interaction preferred compared to interacting by virtual services? Are the requirements the same for a young researcher compared to an older researcher? Are any differences aligned with the preferences of non-academic knowledge workers?

### 3. Method and data

#### 3.1 Survey

The empirical data for analysis was gathered by an online survey conducted by University Properties of Finland in ten Finnish universities in 2013. Both the students and employees of ten universities were invited to answer an online survey through an invitation sent by email. In the survey there was a set of open-ended questions about the research environment. One thousand and twenty researchers answered the questions. Their background information is presented in Table 1.

*Table 1: Background information on the 1 020 respondents to the open ended questions sent to researchers*

Gender \ Age	≤ 30	31–40	41–50	> 50
Woman	165	241	99	80
Man	144	153	74	64

The response rate of the researchers was 10%. The sample was linearized according to both gender and age to match the demography of the researcher population. After linearization the sample size was 390 and distribution for each age group and both genders was the same as the total population of researchers in ten universities. The sample size exceeds the target sample size of 385, which was determined necessary for a margin of error of five percent and a confidence level of 95% with a total population of 10 000 (Holopainen and Pulkkinen 2014).

Questions about the research environment accumulated answers about the requirement for an office's ability to support concentration and face-to-face interaction. The first question was connected to description of the actual workplace and the second question was more about the ideal workplace for research work.

### 3.2 Data analysis

The data analysis included five phases. In the first phase answers were analysed regarding the aspirations for the workplace supporting concentration and face-to-face interaction. Data was analysed by clustering responses according to their thematic similarities and differences. Categories were identified concerning demand for the workplace to support (1) concentration, (2) face-to-face interaction, (3) both 1 and 2 (4) neither 1 nor 2. In this phase a more specific coding protocol (Saldaña 2013) was also developed:

- Category 1 – Concentration. Codes: “private”, “a private room”, “concentration”, “quiet”, “peaceful”, “one’s own work”, “my work”, “my own”, “focus”, “disturbance”, “interruption”, “voice”, “noisy”.
- Category 2 – Face-to-face interaction. Codes: “shared space”, “face-to-face interaction”, “teamwork”, “team members”, “discussion”, “reflection”, “collaboration”, “share thoughts”, “group”, “bounce ideas”, “opinion exchange”, “cooperation”, “new ideas”.
- Category 3 – Both concentration and face-to-face interaction. Codes implying both concentration and face-to-face interaction.
- Category 4 – Neither concentration nor face-to-face interaction. No codes.

In the second phase clustering was implemented by a three-member research group following the protocol developed. The clustering required some intuitive evaluation keeping in mind the goal of finding out what respondents prefer instead of what they will settle for.

In the third phase the sample was linearized to match the researcher population in ten universities. Elimination of the respondents who were over-represented was executed using random numbers. In the fourth phase each category was divided into sub-groups by age.

In the last phase, phase five, the aim was to get a better understanding of the requirements of younger and older researchers. Thematic analysis was conducted by analysing the answers in Category 3, requiring the support of both concentration and face-to-face interaction, in two age groups. The age groups analysed were  $\leq 30$  years and  $> 50$  years. It was assumed that the low response rate would not cause bias to difference between the age groups of the respondents

compared to non-respondents. Analysis was conducted by allocating the responses according to a framework about the nature of places required for the different stages of knowledge creation. The four categories used were connective, structural, formal and reflective places and their nature (Nenonen, 2005), and they are presented in the literature review. The responses were analysed from the point of view of the framework and synthesis of the requirements was developed for each place in both age groups. The figures presented for phase five in Table 2 exceed the amount of respondents because the requirements for physical, social and virtual environments are counted in sum. All the phases of data analysis are presented in Table 2.

*Table 2: The phases of analysis*

<i>Category</i> <i>Phase</i>	<i>Category 1 – Concentration</i>	<i>Category 2 – Interaction</i>	<i>Category 3 – Both</i>	<i>Category 4 – Neither one</i>	<i>Total</i>
<i>Phase 1: Thematic clustering</i>	<i>n = 135 20%</i>	<i>n = 121 18%</i>	<i>n = 419 62%</i>	<i>n = 345</i>	<i>n = 1020 n= 675 100%</i>
<i>Phase 2: Coding</i>	<i>n=115 17%</i>	<i>n=120 18%</i>	<i>n=440 65%</i>	-	<i>n = 675 100%</i>
<i>Phase 3: Linearization</i>	<i>n = 55 14%</i>	<i>n = 62 16%</i>	<i>n = 273 70%</i>	-	<i>n = 390 100%</i>
<i>Phase 4: Age-groups</i>					
<i>Age ≤ 30</i>	<i>n = 15 17%</i>	<i>n = 20 23%</i>	<i>n = 52 60%</i>		<i>n = 87 100%</i>
<i>Age 31–40</i>	<i>n = 17 13%</i>	<i>n = 19 15%</i>	<i>n = 94 72%</i>		<i>n = 130 100%</i>
<i>Age 41–50</i>	<i>n = 9 12%</i>	<i>n = 11 14%</i>	<i>n = 58 74%</i>		<i>n = 87 100%</i>
<i>Age &gt; 50</i>	<i>n = 11 12%</i>	<i>n = 12 13%</i>	<i>n = 72 76%</i>		<i>n = 95 100%</i>
<i>Phase 5</i>					
<i>Thematic clustering</i>	<i>Connective</i>	<i>Structural</i>	<i>Formal</i>	<i>Reflective</i>	
<i>Age ≤ 30</i>	<i>n = 22</i>	<i>n = 19</i>	<i>n = 62</i>	<i>n = 76</i>	<i>n = 52</i>
<i>Age &gt; 50</i>	<i>n = 51</i>	<i>n = 47</i>	<i>n = 77</i>	<i>n = 93</i>	<i>n = 72</i>

In terms of reliability, one aimed to increase it during analysis (Stake 2010, Creswell 2014). Phase one was conducted by only one researcher and the codes were described before phase two. Phase two was peer reviewed and some sections were compared and cross-checked by other members of the research group of three researchers. Linearization was conducted after coding and categorization, to find out the effect it had on the distribution of each category. Internal consistency was analysed in phase four. Distribution in each category was not affected by dividing responses by the gender of respondents. However, age had an effect on distribution. Since data is quantified from quality data by clustering answers, any statistical analysis is merely indicative. Chi-square test did not show any influence by gender on the distribution of clusters: ( $\chi^2$ ) = 0.77,



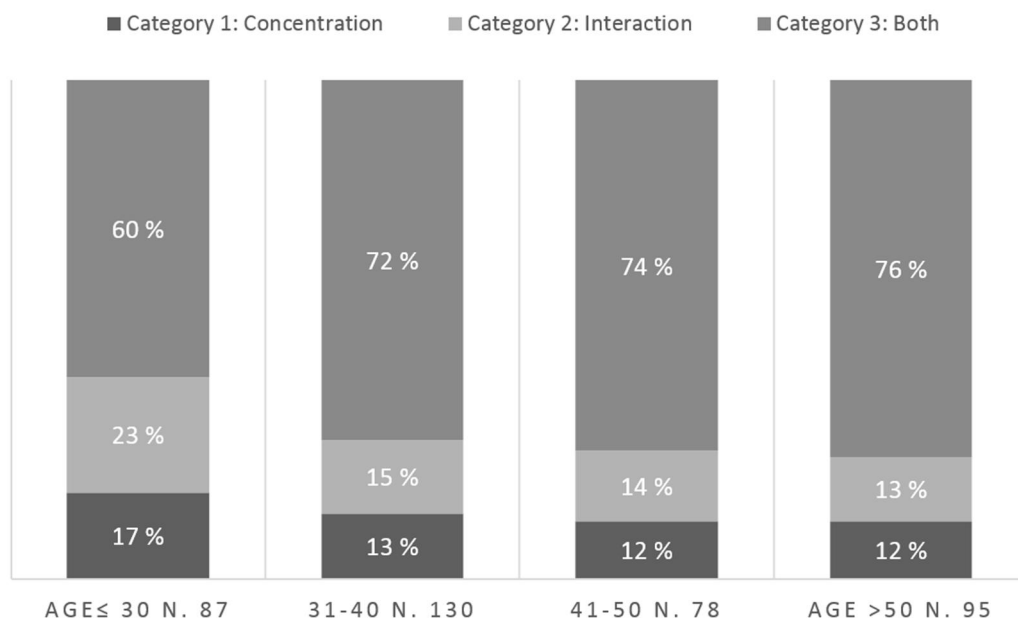
df = 2 and p = 0.681. Age had an influence on the distribution of clusters: ( $\chi^2$ ) = 731.38, df = 6 and p < 0.001. (Holopainen and Pulkkinen 2014).

The main guidelines for the distribution were consistent throughout each phase. The main emphasis was on Category 3, the requirement for the workplace to both support concentration and face-to-face interaction. The fifth phase was first conducted alone and then with a group of three researchers. Thematic clustering turned out to be less straightforward in phase five compared to phase one. It required continuous discussion of the results within the group of researchers conducting the analysis. Several iterations were conducted to confirm the interpretation when reporting the results.

## 4. Results

Three thematic categories were identified, concerning the demand for the support of (1) concentration, (2) face-to-face interaction and (3) both of the previous points. The majority of academic researchers emphasise the requirement for supporting both concentration and face-to-face interaction.

There are differences between age groups in terms of requirements. The responses from older researchers (> 50) have stronger representation (76%) in Category 3 compared to the responses from younger researchers ( $\leq 30$ ) (60%). Analysis indicates that the emphasis of the requirements of an academic workplace lie on it being a place that supports concentration and face-to-face interaction. This is visible in Figure 1.



*Figure 1: Distribution to Categories requiring support for concentration, face-to-face interaction or both. Each age group had the most requirements for Category 3: on requiring support both for concentration and face-to-face interaction. The older generation were more represented in the Category 3 compared to the younger generation.*

The results concerning what is required from workplaces and the differences and similarities between generations are presented in the next chapters. The results are presented from the point of view of the framework used. The framework was about the nature of places required for the different stages of knowledge creation and it was presented in the literature review (Nenonen, 2005).

The majority of both older and younger researchers emphasise the requirement for supporting both concentration and face-to-face interaction. When analysing that from the point of view of the framework, one can state that demands for concentration can be mapped as demands for a “formal place”: an internally open formal place supporting individual work. The analysis of requirements concerning face-to-face interaction indicate that most of them can be considered as demands for a “reflective place”: an internally open informal place, supporting reflection within one’s research group. Analysis of the requirements concerning face-to-face interaction also indicate that some of them can be considered as demands for a “connective place” supporting reflection with external partners in an externally open, informal place, and some of them can be considered as demands for a “structural place” that is externally open and has a formal atmosphere, like a meeting room.

As a similarity, both age groups emphasise requirements typical of internally open places more than they emphasis requirements for externally open places. As another similarity, both age groups emphasise formal and informal places equally. As a difference, analysis indicates that when comparing aspirations for internally open places, young researchers demand them more often. Analysis also indicates that when comparing aspirations for externally open places, older researchers demand them more often than younger researchers. Older researchers seem to require support for a larger interaction network: international connections and interaction outside their research team and university.

As another difference, several older researchers want a private office with private meeting facilities in it, as well as a sofa for rest and as a comfortable reading place. Several younger researchers also describe the same aspiration for the workplace supporting concentration, having meeting facilities and being a place to rest and read, but they indicate that access to shared places with diverse functions would satisfy their needs.

An internal lounge and café spaces dedicated to one’s team were the main source of face-to-face interaction, which both age groups suggest to be the primary source of new ideas. The older researchers express their requirements connected to an internally open informal place as a pleasant place for easy access interaction in order to share ideas. Some respondents of the older group mention serendipitous encounters with international visitors to be the source of new ideas. Younger researchers set requirements like having inviting places for interaction and inspiration for new ideas. In such places many younger researchers felt that there is licence to ask for advice.

The majority of older researchers want to have a private room as a space for concentration. Some of older researchers indicate that they just want to have access to a place dedicated to concentration. The majority of older researchers want to have virtual connections to information,

such as electronic databases/journals, and services to help using virtual technology. About half of the younger researchers want to have a room of their own; the rest of them want to have access to a peaceful place where they can concentrate. Respondents wish for access to virtual connections to information, such as electronic databases/journals.

More than half of the older researchers require the characteristics of connective place, like landing places (e.g. desks) for national and international partners and services to support virtual communication. Less than half of the younger researchers describe similar requirements to the older researchers. They also ask for possibilities to enjoy the existing social connections of older researchers.

Older researchers require serviced meeting places. Younger researchers want to have high-quality meeting places. Both requirements can be considered as requirements for structural places.

The summary of the results of the last phase are in the following figure, Figure 2.

Tacit to tacit	Socialization	Externalization	Tacit to explicit
Externally open, informal	<b>Connective place</b> <b>&gt; 50:</b> Landing places for national and international partners and services to support virtual communication. <b>≤ 30:</b> Senior researcher's international contacts to be shared. Services to support virtual communication.	<b>Structural place</b> <b>&gt; 50:</b> Serviced meeting places <b>≤ 30:</b> High-quality meeting places	Externally open, formal
	<b>Reflective place</b> <b>&gt; 50:</b> Pleasant places for easy access interaction in order to share ideas. <b>≤ 30:</b> Inviting places for interaction. Inspiration for new ideas. A licence to ask for help.	<b>Formal place</b> <b>&gt; 50:</b> A private office that can fulfil all functions and serviced virtual connections to electronic databases/journals. <b>≤ 30:</b> Access to diverse places that can fulfil diverse functions and connectivity to digital environment.	
Tacit to explicit	Internalization	Combination	Explicit to explicit

Figure 2: The requirements of an academic workplace in age groups  $\leq 30$  and  $> 50$ .

## 5. Discussion and Conclusion

The aim of this paper was to investigate the workplace requirements of academic workplaces for researchers: What is required from workplaces that support both concentration and face-to-face interaction and are there any differences between generations in regard to this? The results are described in the previous chapter and the figure 2 above by using the framework of classification developed to understand the nature of workplaces suited for knowledge creation as supporters for the different phases of knowledge creation. The results in this paper are mainly aligned to the workplace preferences of different generations presented by Rothe et al. (2012) and did not

conflict with the literature review about the nature of academic work. The findings in this paper also support previous research about informal face-to-face interaction as a source of new ideas.

The results give new insights into what researchers of different ages prefer in their work environments. The information of user preferences is valuable both for user organizations and facilities management. Based on the results it is evident that the workplace for researchers is no longer only a private office in an ivory tower: one has to pay more attention to the diverse nature of workplaces. Researchers mainly require internally open places but they do also require externally open places. Analysis also indicates that when comparing aspirations for externally open places, demand is stated more often in responses from older researchers, who seem to require support for larger interaction network. Both younger and older researchers require formal places as much as informal places.

As a limitation, this research does not segregate diverse disciplines and the different requirements they might have. In order to gain more knowledge on this matter, a study that segregates diverse disciplines should be conducted. Additionally the cultural context has to be taken into account when generalising the results as this research is limited to ten universities in Finland.

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# Observing repair and maintenance costs using the example of the German ecclesiastical building stock

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## Abstract

Knowledge of repair and maintenance costs is the major key to optimize the future budget. Cost-optimized real estate management can only be provided if the causal relationship between repair and maintenance costs and their influential factors is known. In times of declining tax revenues and decreasing numbers of church members, church facility managers today are forced to reduce their maintenance budget.

Regarding budget planning, repair and maintenance costs are the most relevant part of buildings' running costs. They can be differentiated in continuous and inordinate costs. For budget planning the inordinate costs are difficult to value, because they are very cost-intensive and appear unsteady.

Since they represent the most important part of the ecclesiastical building stock, the emphasis of this study lies on sacral buildings. Analyzing the inhomogeneity of these buildings regarding building age and size, historical value and specific conditions (e.g., bell-towers) and considering the lack of specific maintenance cost know-how, most important influential cost factors on repair and maintenance costs are determined in the current study. In the first step, a literature review identifies the most common influential factors on maintenance cost of different types of buildings, e.g., office buildings. In the second step, the relevance of these factors is verified and new factors are determined with the help of expert interviews, considering the special conditions of sacral buildings.

The result of the study is a detailed table with the relevant influential factors on repair and maintenance costs (respecting the maintenance strategies, the building characteristics, location, condition, and usage) for sacral buildings. The described study serves as a base for an empirical research with several hundred buildings.

**Keywords:** Repair costs, maintenance costs, ecclesiastical building stock, sacral buildings, Germany

# 1. Introduction

Today, the existing building stock in Germany is of increased interest for the ecclesiastical management. In times of decreasing tax revenues the managers are forced to organize maintenance in a way that is optimized with respect to use and costs. Compared to others, managers of ecclesiastical real estate are in charge of a great variance of buildings. In the ecclesiastical building stock, sacral buildings are the most important ones and suffer most from the lack of specialized budgeting know-how for repair and maintenance.

Nonetheless sacral buildings are not only a special type of building: They often have relevance for towns setting and cities' history, too. Some of them have a complex building history that evolved over different architectural styles and periods. Often they are a listed monument. Additional to that, church buildings have special relevant characteristics, which differentiate them from other buildings: Firstly, the towers, mostly with bells, have to be mentioned. Secondly, valuable facilities like historical altars and seats, historical wall paintings and objects of art and also organs have to be considered regarding the interior space.

Systematic real estate management, which could be located in the bishop's administration, is hindered by the owner's structure and tax system. Each parish is the owner of its buildings. It is responsible for the buildings' use and also their maintenance. In case of a larger renovation, they can ask the financial administration of the diocese for a subvention, which in the past was often granted without problems.

Reliable maintenance cost estimation is also needed on the level of a parish. Nowadays, formerly independent parishes are united into bigger ones (Freiburg 2015). Often, such a new parish has to reduce its building stock because of less churchgoers and reduction of the number of priests. It is not possible to offer religious services in every church anymore. Therefore, the number of church buildings has to be reduced.

In times of decreasing taxes, the current subvention system has to be reconsidered. To calculate the future maintenance budget, the facility managers of a diocese have to know which amount of maintenance costs they should expect in the following years (even in a mid-time and long-time perspective). The question underlying is how many buildings they can afford in the next 10 to 20 years and, in consequence, how much financial reserve has to be built up, starting from now.

In this context, cost-optimized real estate management can only be provided if the causal relationship between maintenance costs and their influential factors is known. The first steps (literature review and evaluation of relevant influential factors) of the intended research study are described in the following.

This project is supported by two catholic dioceses in the south of Germany.

## 2. Objectives

The present research study wants to examine relevant causal interrelations that exist between repair and maintenance costs of sacral buildings and their influential factors. Thereby the study takes a wide range of both theoretically and practically relevant factors into account.

In a first step, a literature review gives an overview of different approaches used in former studies. In a second step, relevant factors are carved out by a literature review and are evaluated with expert interviews (Chapter 3). The results are presented in Chapter 4 and summarized in Chapter 5. They serve as the foundation for an empirical study, which is planned. An outlook of the following steps is given in Chapter 6.

## 3. Literature research and limitations

In the literature, two different main approaches can be found. One group of researchers built on the idea to use maintenance as described in German standard DIN 31051. Other researchers have analyzed occupancy cost as defined in German standard DIN 18960. The latter group investigates operating and repair costs of buildings. Table 1 gives an overview of the two corresponding norms. DIN 31051 describes measures of maintenance like service, inspection, repair and improvement. DIN 18960 is the “classic” norm for cost. It can also be used for life-cycle analysis according to ISO standard 15686-5 “Buildings and constructed assets – Service-life planning, Part 5: Life-cycle costing”, 2008. It points out four different cost groups for the phase of use of a building: The capital costs (cost group 100), facility management costs (200), operating costs (300) and repair costs (400).

*Table 1: Structure and content of DIN 18960 and DIN 31051 (German Institute for standardization)*

<b>DIN 18960</b>	<b>Occupancy costs</b>	<b>DIN 31051</b>	<b>Maintenance fundamentals</b>
CG	Cost group	No.	Measures
100	Capital costs		
200	Object management costs		
300	Operating costs		
	...		
340	Inspection and maintenance of building construction	4.1.2	Maintenance Service
350	Inspection and maintenance of technical installation	4.1.3	Inspection
	...		
400	Repair costs		
410	Repair costs of building construction	4.1.4	Repair
420	Repair costs of technical installation		
	...		
440	Repair costs of fittings, furnishings and equipment	4.1.5	Improvement

Cf: Bartsch et al. (2008), p. 76



As a representative for that group, Bahr et al. (2008) can be mentioned. Their study's aim was to find out a better budgeting method for the public building stock. Four different approaches are considered for determination of maintenance budgets: key data-oriented or history-based budgeting, value-based budgeting, analytical calculation of maintenance budgets, and budgeting by condition-description. All these budgeting methods are analyzed in the BEWIS research project, which investigated maintenance data of 17 existing public buildings. The research team compared real budget with budget calculation using the four different methods. They discovered that all methods fail to satisfy the needs of a public Facility Management (discrepancy up to 200% between the calculated value and real costs). Based on this analysis, a new method called PAPI-Factor was developed. Using replacement value as the base, a literature review was performed and identified four other cost drivers: Year of construction, type of use, geometrical dimensions (building size dimensions) and quality of construction. Thereby, different factors are developed for continuous and inordinate maintenance measures (Bahr 2008).

Bossmann (2011) adopted this approach for sacral buildings using the example of 30 protestant churches. Analyzing the empirical data with statistical methods, the following significant influencing variables were identified: building age, building geometry, architectural complexity and the status as listed building (Table 2). He changed the calculation base from replacement value to the average maintenance costs per year for all buildings in the portfolio in relation to the building volume.

*Table 2: Comparison data base, kind of costs and influential factors I*

Study	Type of utilization and data base	Consumption and Costs	Influential factors
Bahr (2008)	17 office and school buildings	Maintenance costs	Building characteristics, Utilization
Bossmann (2011)	30 sacral buildings	Maintenance costs	Building characteristics, Preservation order

Budgeting and benchmarking together is the approach of Stoy and a team of researchers at the Institute for Construction Economics of the University of Stuttgart. They analyzed occupancy cost in empirical studies of more than 100 buildings of the same type. Stoy (2005) analyzed cost data of office buildings, Beusker (2012) used this approach for school buildings, and Hawlik (2015) adapted it to day-care facilities for children. In each case in a first step the researcher developed an expert interview to find out the possible cost drivers for each building type. The interview was structured in four main parts: Building use, building parameters, place related information and strategies. Based on expert answers, a questionnaire was developed and used for collecting building information, also using construction plans. The questionnaire asked for basic data like the age and place-related information, standard and age of technical installation, type and condition of construction and technical installation, and also the size, type, and condition of the related surrounding. Cost data was contributed by the finance department of the respective partners.

*Table 3: Comparison data base, kind of costs and influential factors II*

Study	Type of utilization and data base	Consumption and Costs	Influential factors
Stoy (2005)	116 office buildings	Capital costs Object management costs Operating costs Total maintenance costs	Strategy Building characteristics Utilization, Location
Beusker (2012)	130 school buildings	Operating costs Repair costs	Strategy Building characteristics Utilization, location
Hawlik (2015)	125 Day-care facilities for children	Personal costs (educational personal) Operating costs Repair costs	Strategy Building characteristics Utilization, Location

By analyzing cost data und building information (use, building parameters, place related information and strategies) with statistical methods, this group of researcher identified the cost drivers for each cost group of DIN 18960. The identified cost drivers for different cost groups are shown in Table 3.

A third group of researchers – especially with focus on benchmarking – analyzed more than hundred buildings, but with less building information. The OSCAR (Office Service Charge Analysis Report, Jones Lang LaSalle) and the FM- Benchmarking report are mentioned as typical representatives. Different factors are used as building characteristics: Building age and floor size (FM Benchmarking), but also numbers of levels and quality standard (particularly air conditioning). The OSCAR also takes the location and the technical standard into account, the FM Benchmarking report refers to the intensity of use and cleaning. An overview is given in Table 4.

*Table 4: Comparison data base, kind of costs and influential factors III*

Study	Type of utilization and data base	Consumption and Costs	Influential factors
JLL OSCAR 2015	219 office buildings	Capital costs Object management costs Operating cost	Building characteristics Location
FM Benchmarking report 2015	4,578 buildings (different types of Utilization)	Operating costs Repair costs	Building characteristics, Intensity of use and cleaning

## 4. First results

The current research, the methods introduced by other researchers of the Institute for Construction Economics are continued. In all these studies, the relevant influential factors were identified by an expert interview. Therefore, fifteen experts were interviewed.

The interview was realized with an almost equal number of participants from the ecclesiastical administration (finance and administration experts), architects (specialized on sacral architecture) and others (user, specialist engineers, consultants). Further information concerning the expert positions and experience is shown in table 5.

*Table 5: Interviewed experts*

Expert	Position/Field	Number of interviews
Administrator	Head of diocesan building management department	2
	Department head of diocesan finance management	1
	Assistant, diocesan administration	2
Architect	Head of diocesan building construction department	2
	Project leader, diocesan building construction department	2
	Owner of an architectural firm	1
Engineer	Owner of an engineer company	1
	Senior researcher, department of architecture	1
User	Priest (experience with building activity)	1
Consultant	Director (consulting agency)	1
	Project leader (consulting agency)	1

The interview was structured in these four parts: Utilization, buildings characteristics, location and strategy. Construction and technical characteristics refer to the German DIN 276. All relevant factors of the above mentioned studies were listed. Additionally, some special sacral buildings related factors were added.

The experts were asked to do the following:

- Identification of cost drivers (from the 40 suggested drivers of literature research, see Table 6)
- Denomination of further cost drivers
- Weighting of each cost driver (on an ordinal scale from 1 to 10)

*Table 6: Proposed influential factors and their characteristics*

Factor group		Influential factor (Variable)	Characteristic
Use	1	Type of (additional) use	Kind and extensiveness of additional use
	2	Intensity of use	Average services time
	3	Pastoral relevance of the sacral building	National, regional, local relevance
<b>Building characteristics</b>			
Basic information	4	Building age	Year of construction
	5	Architectural design	(Declaration)
	6	Significant extension and transformation	(Declaration)
	7	Preservation order	Yes/no
	8	Building size	Gross floor area in m <sup>2</sup> , Volume in m <sup>3</sup>
	9	Orientation	East-west, other, no orientation
	10	Typology of cubature	One-wing, multi-wing church, central-plan building, free form
	11	Towers	Number, Height, with/without bells
	12	Building height	Height in m
	13	Compactness	Surface in m <sup>2</sup> /volume in m <sup>3</sup>
	14	Cellar/Crypt	Yes/no
Construction characteristics	15	Foundation	Type, material and condition of foundation
	16	External walls	Type, material and condition of
	17	Internal walls	Type, material and condition of internal walls
	18	Ceilings	Type, material and condition of ceilings
	19	Roofs	Construction, material and condition of roofs
	20	Fittings	Type, material and condition of fittings
Technical characteristics	21	Sanitation, water supply system	Standard
	22	Heating system	Energy source, age, standard, condition
	23	Air treatment system	Standard
	24	Power installation	Age, standard
	25	Communication systems	Standard
	26	Transport system (lift)	Exist yes/no
	27	Function-related equipment and fitments	Yes/no, system
	28	Building automation	Yes/no
Fittings/Setting	29	Artistic value	Description, value
Location	30	Outdoor facility	Type, size, condition
	31	Topography	Flat, sloped
	32	Soil conditions	Condition
	33	Building situation	Detached /cramped
	34	Climatic conditions	Temperature, humidity (average)
	35	Cyclical influence	Urban, suburban, rural
	36	Church tax	Tax in €/member in a parish
Strategy	37	Diocesan subvention	Limitation (in €)
	38	Procurement strategy	Declaration of strategy (choice)
	39	Pastoral development concept	Exist yes/no
	40	Coordination effort (church and municipal administration)	High/low effort
New (Expert declaration)		Demanding member (related to the building)	Yes/no
		Engagement of honorary and pastoral members	High/low engagement
		Organ	Exist yes/no, age, value, size
		Requirements of nature protection	Yes/no (declaration)

Not only the factors, but also their measurable characteristics were suggested and also evaluated by the experts. The results are shown in Table 7. Factors that got less than 3 points on average have no or only minimal influence and won't be regarded anymore. Factors with 7 or more points on average are regarded to have high influence, and factors with 3 to 7 points are assumed to have medium influence.

*Table 7: Results of expert interviews*

Ranking	Influence	Determination of influential factors
1	High	External walls
2		Towers
3		Ceilings
4	Medium	Heating system
5		Artistic value
6		Preservation order
7		Fittings
8		Power installation
9		Foundation
10		Architectural design
11		Roofs
12		Building size
13		Function-related equipment and fitments
14		Soil conditions
15		Intensity of use
16		Building age
17		Church tax
18		Internal walls
19		Typology of cubature
20		Diocesan subvention
21		Procurement strategy
22		Building height
23		Topography
24		Type of (additional) use
25		Climatic conditions
26		Cyclical influence
27		Coordination effort (church and municipal administration)
28		Demanding member (related to the building)
29		Pastoral relevance of the sacral building
30		Engagement of honorary and pastoral members
31		Organ
32		Requirements of nature protection

## 5. Summary

The experts confirm the relevance of building characteristics. Especially the outer shell - the external walls and the towers - seems to have high relevance regarding the maintenance costs. According to the experts' knowledge, the costs for scaffolds rise exorbitant, with the highness of the towers. Even bells cause additional maintenance costs.

Furthermore, the influence of the ceilings is appraised as high. The interviewees pointed out that the interior situation (design, material, condition, artistic value) of the sacred space has high relevance. Also, the building age, building size (volume), and the status as listed monument are important and have to be considered in a further research. Another important point is the artistic value of the sacral building and fittings/settings.

For years, sacral buildings have been buildings with a low level of technical installation. However, according to expert opinions, it seems that in the future, sacral buildings (that are still intended to be used) will have higher level of technical installations. To provide more comfort for the churchgoers during sacral ceremonies and concerts etc., technical installations become much more relevant. First the heating system has to be mentioned, followed by public address systems (combined with hearing impaired systems) and illumination systems.

Also, the users' behaviour and activity of each parish seem to be very relevant for maintenance strategy and consequently for the costs. According to the experts, there is a great variance of users' demands, which are often the starting point for maintenance and modernization projects.

Regarding the location, the experts affirm the known factors (climatic situation, cyclical influence and soil condition of the building plot). Additionally, the experts specify also the tax income in relation towards the number of members in each parish.

The experts declare that most of the parishes do not have any maintenance strategy: Only in the case of a break down, the need of repair or renewal appears. The diocesan subvention often is the only way to finance big maintenance measures. It is connected with conditions (like financing plan and time interval for defined maintenance measures). A positive cooperation with municipal administration helps the church administration to realize the target project.

The question concerning surroundings was cancelled. It was not possible to define a related zone to the church building. Organs and bells will be considered in the upcoming research.

## **6. Outlook and conclusion**

The presented study is the base of an empirical research. It is intended to collect data of about 400 sacral buildings: Building information, as given by expert interviews, shall be connected with the cost data as provided by church facility management. With the help of statistical methods, the most important influential factors on costs shall be found and evaluated.

The following steps are suggested for the study:

- Transfer of the expert interview results into a questionnaire
- Pilot study with approx. five buildings of every participating diocese to proof the procedure and the questionnaire, parallel collection of cost data
- Adaption of the questionnaire if necessary
- Phase of collecting building and cost data
- Statistical analysis like regression models to develop cost indicators
- Transfer of the theoretical results into practice

The questionnaire will be edit by the architects (building and technical characteristics) and administration stuff (usage, location and strategies) of the diocese. Information about climatic condition, like the average temperature and humidity can be found in climatic publication of meteorological services. The Federal Statistical Office (Destatis) provides indexes for development of prices, which will be used to respect the cyclical influence.

The finance administration of the dioceses will provide cost data. The cost data will include periodic costs (e.g., yearly maintenance service of the heating system) and costs which appear in irregular, often long intervals (e.g., repair and maintenance). The project intends to use cost data of the last five years.

Employing statistical methods like regressions models, the correlation between the costs and the influential factors should be revealed and cost indicators will be generated. The determination of cost indicators requires a consistent definition of the underlying cost data (repair and maintenance costs), a consistent definition of an appropriate reference value e.g. gross external floor area GEFA, and the provision of further descriptions. In a further step, the results will be transferred into practice e.g. by the provision of cost indicators for maintenance measures.

Today, church facility managers do not know their future maintenance budget requirements. This is due to the fact that general information about repair and maintenance costs and their significant influential factors are not available in a structured way. In times of expected decreasing tax incomes and high responsibility for valuable buildings, accurate maintenance planning is needed. The goal of this project is to fill this gap. Finally, this project provides support for church facility managers to calculate the maintenance costs for sacral buildings in a medium and long term perspective.

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# Evaluation to Condensation Prevention Performance of Double Glazing Window with Real Scale Test

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## Abstract

Condensation prevention performance plays significant role in the improvement in occupants' living satisfaction and reduction of defect. Civil complaint about residential environment such as the condensation problems are rapidly increasing by the growing interest in residential environment from improvement of the quality of life. In the case of double glazing window installed for a expanded balcony apartment, the inside window condensation as well as the complaints about the outdoor window condensation is also tendency to surge. This study shows analysis of TDR(Temperature Difference Ratio) for inside window surface and intermediate space air temperature on according to full scale mock-up test. It is found that Case 4(Low-E is located in outside) only it satisfied the requirements TDR conditions( $-15^{\circ}\text{C}$ ) and air temperature in intermediate space was significantly increased. The results of this study can significantly contribute to the improvement in condensation prevention performance.

**Keywords:** Condensation prevention performance, TDR(Temperature difference ration), Full scale mock-up test, Double glazing window

# 1. Introduction

Windows have relatively low thermal insulation performance. Thus, a decrease in the condensation prevention performance of windows is highly likely not only to increase the risk of surface condensation but also to cause secondary damages such as the occurrence of fungi and the detriment to finishing materials.

The existing windows mainly serve for heat loss prevention and ventilation. However, residents are increasingly expressing concerns over residential environment with the improvement of the quality of life, and filing complaints with the increases in defects caused by condensation. Besides, complaints are rapidly increasing about the condensation on not only the inside but also, recently, the outside of windows in domestic common housing where double-glazing windows are mostly applied with an extension of balcony.

As window condensation is very easily visible in daily life, it has been the major causes of residents' complaints and the subsequent defect repair cost. Yet, it is difficult to quantitatively assess the cost incurred from window condensation.

So, 'Condensation Prevention Design Criteria for Common Housing' was established based on Public Notice No. 2013-854 by the Ministry of Land, Infrastructure and Transport for more than 500-unit common housing effective from May 7, 2014.

However, cost-effective window products are not yet sufficiently developed to realize condensation prevention performance under 'Condensation Prevention Design Criteria for Common Housing'. Thus, a development of window products to enable cost saving and to meet condensation prevention performance at the same time is emerging as an important issue.

The method for evaluating condensation prevention performance through the existing mock-up test is not consistent with the site conditions and the sizes of windows that apply to real common housing. Consequently, real sites are experiencing condensation prevention performance different from the result of mock-up test.

So, this study intends to test actual condensation prevention performance of double-glazing windows applied to common housing through full-scale performance test, and also to derive an optimal combination to enable cost saving and to meet condensation prevention performance at the same time by inducing an increase in the temperature of air space through the combination of major structural members of the existing windows.

# 2. Methodology

Full-scale performance test was conducted for a total of 5 cases applied to domestic common housing according to the location of low-e glass and the type of spacer. A performance test was conducted in 'Condensation Mock-up Laboratory' in Residential Performance Research Center

of S construction company located in Yongin, Gyeonggi-do, using a testing method under KS F 2295 and ‘Condensation Prevention Design Criteria for Common Housing’.

## 2.1 Design Criteria and Evaluation Methods

The location of measurement and the conditions for a test (Area II: -15°C) was determined and a test was conducted according to a test method under KS F 2295. ‘Condensation Prevention Design Criteria for Common Housing’ uses Temperature Difference Ratio (hereinafter referred to as TDR) as the index to evaluate condensation prevention performance. TDR is the relative ratio of a difference between indoor air temperature and the indoor surface temperature of an target part to a difference between indoor air temperature and outdoor air temperature. TDR is calculated according to the following formula and ranges from 0 to 1.

$$\text{TDR} = \frac{\text{Indoor air temperature} - \text{Indoor surface temperature of an applicable object}}{\text{Indoor air temperature} - \text{Outdoor air temperature}}$$

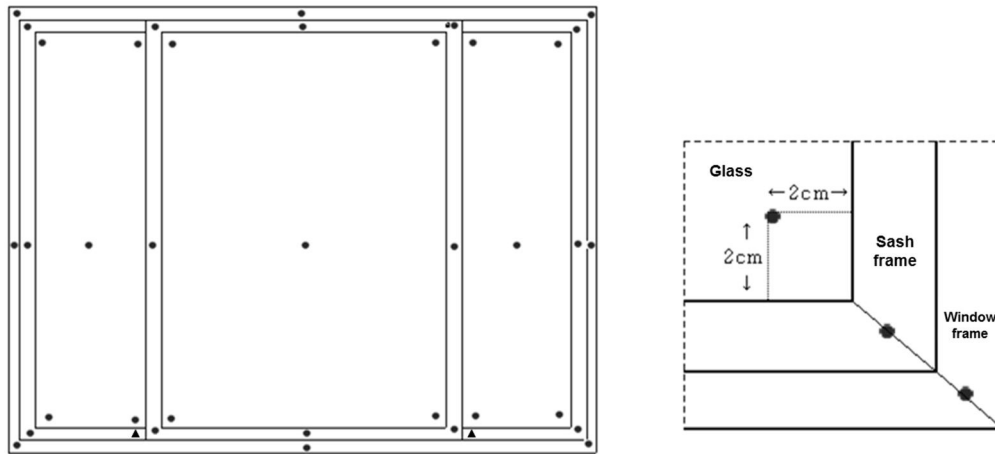
25°C was set for indoor temperature and 50% for indoor relative humidity as indoor conditions. This test applied -15°C, which is the criterion of area II, as outdoor air temperature (Table 1)

*Table 1: Criteria for condensation prevention performance by major parts considering areas*

<i>Target part</i>		<i>TDR Value</i>		
		<i>Area I</i>	<i>Area II</i>	<i>Area III</i>
<i>Window exposed directly to outdoor air</i>	<i>Central part of glass</i>	<i>0.16 (0.16)</i>	<i>0.18 (0.18)</i>	<i>0.20 (0.24)</i>
	<i>Corner of glass</i>	<i>0.22 (0.26)</i>	<i>0.24 (0.29)</i>	<i>0.27 (0.32)</i>
	<i>Window frame and sliding frame</i>	<i>0.25 (0.30)</i>	<i>0.28 (0.33)</i>	<i>0.32 (0.38)</i>

To calculate TDR value on the inside of a window of a specimen, the surface temperature of the total 39 points were measured with addition of 2 points of parts in low thermal insulation to 37 points under ‘Condensation Prevention Design Criteria for Common Housing’, and, to identify the change in condensation prevention performance according to the change in air temperature of air space, air space was divided into upper part, middle part, and lower part and the air temperatures of each part were measured (Figure 1 and Table 2).

If using figures refer to them in the main text and keep reasonably simple, using black and white or grey scale, but not colour. Paste in as picture and use the style of the following example for the heading text.



● : Example of locations for calculation

▲ : Addition of locations for calculation (on parts in low thermal insulation)

Figure 1: Locations for TDR calculation (addition of parts in low thermal insulation)

Table 2: Criteria for condensation prevention performance by major parts considering areas

Classification	Locations for calculation
Air space	
Window indoor surface temperature	

## 2.2 Realization of Full-scale Double-glazing Windows

The method for evaluating condensation prevention performance through the existing mock-up testing is not consistent with the site conditions and the sizes of windows that apply to real common housing. Consequently, real sites are experiencing condensation prevention performance different from the result of mock-up testing.

This experiment tested actual condensation prevention performance of a double glazing window applied to common housing, adapting the conditions of real construction sites and the size of double-glazing windows applied to real common housing (Figure 2 and 3).

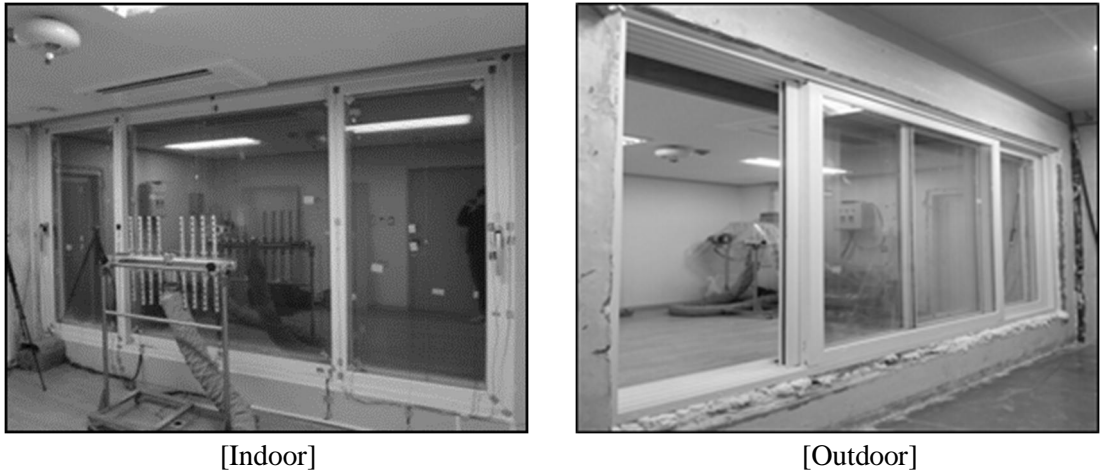


Figure 2: Full-scale mock-up laboratory: indoor(left), outdoor(right)

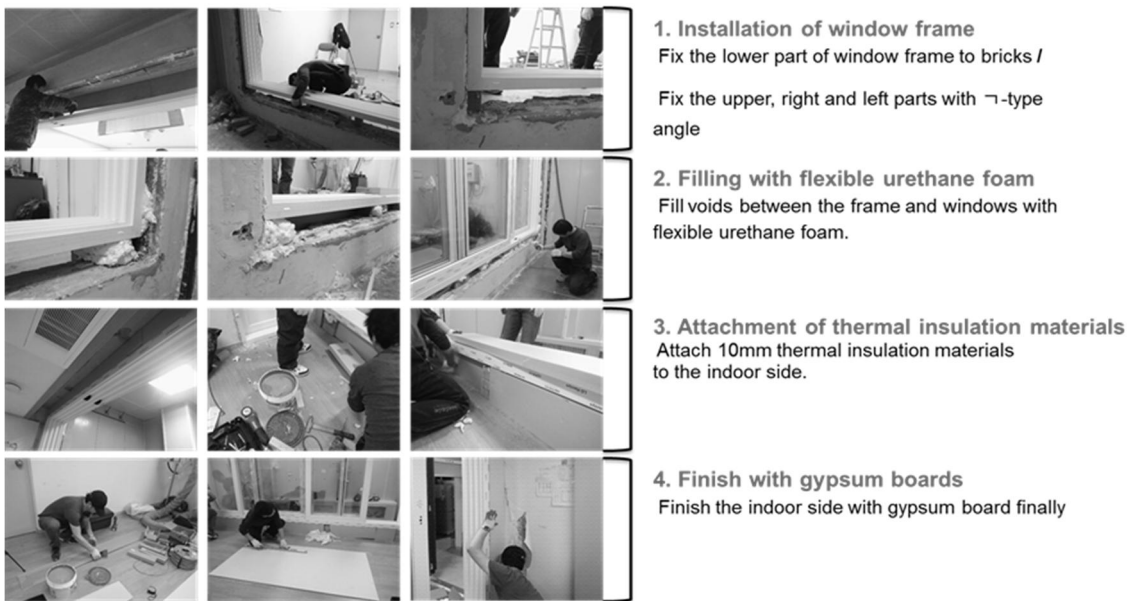


Figure 3: Double-glazing window installation method

### 2.3 Case

A total of 5 cases were selected according to the locations of low-e glass and types of spacer in the inside and outside window of a double-glazing window. Low-e glass was classified into indoor and outdoor glass depending on the location, and glass spacer was classified into TPS thermal insulating spacer and normal aluminum spacer. The thickness of insulating glass was all 22mm, and 246 mm PVC was uniformly applied to the frames (Table 3).

Table 3: Experiment case summary

Case	Outside					Inside				
	Thickness	Specification of glass	Location of low-e glass	Spacer	Type of gas	Thickness	Specification of glass	Location of low-e glass	Spacer	Type of gas
Case1	22	5CL+12Air+5CL	-	AL	Air	22	5CL+12Air+5LE	●	AL	Air
Case2	22	5CL+12Air+5CL	-	AL	Air	22	5CL+12Air+5LE	●	TPS	Air
Case3	22	5CL+12Air+5CL	-	TPS	Air	22	5CL+12Air+5LE	●	TPS	Air
Case4	22	5CL+12Air+5LE	●	TPS	Air	22	5CL+12Air+5CL	-	TPS	Air
Case5	22	5CL+12Air+5LE	●	AL	Air	22	5CL+12Air+5LE	●	TPS	Air

### 3. Result

5 cases were selected according to the locations of low-e glass and types of spacer in the inside and outside window of a double-glazing window, window indoor surface temperature was measured through full-scale performance test for condensation prevention, and TDR was calculated.

#### 3.1 Comparison of Air Temperature of Air Space

The mean temperature of air space of Case4 was highest, followed by Case5, Case2, Case3, and Case1 in order. In particular, the mean temperature of air space of Case 4 was around 2 °C higher than that of Case 5 where low-e glass was applied to both the indoor and the outdoor, and rose by around 4 °C compared with Case 3 where only the location of low-e glass was differently applied to the outdoor and the indoor. In other words, as the location of low-e glass is set to the outside window like Case 4, indoor warm air is relatively free to flow in air space, and accordingly convection in air space increases the air temperature of air space (Figure 4).

#### 3.2 Comparison of Indoor Surface Temperature of Parts in Low Thermal Insulation

Using the measurement values of window indoor surface temperature of parts in low thermal insulation, TDR was calculated, and the compatibility was evaluated for the criteria for condensation prevention performance in the criterion of area II under ‘Condensation Prevention Design Criteria for Common Housing’ (Figure 5).

According to the result of a review over the compatibility with the criteria for condensation prevention performance, only Case4 and Case5 satisfied the criteria of area II under ‘Condensation Prevention Design Criteria for Common Housing’, and in the mean window indoor surface temperature of parts in low thermal insulation, Case4 was highest, followed by Case5,

Case3, Case2 and Case1 in order. In other words, condensation prevention performance of Case 4 turned out most excellent. In short, the location of low-e glass set to the outside window brings about an increase in the air temperature in air space, and accordingly the window indoor surface temperature of double-glazing windows increases, which improves condensation prevention performance.

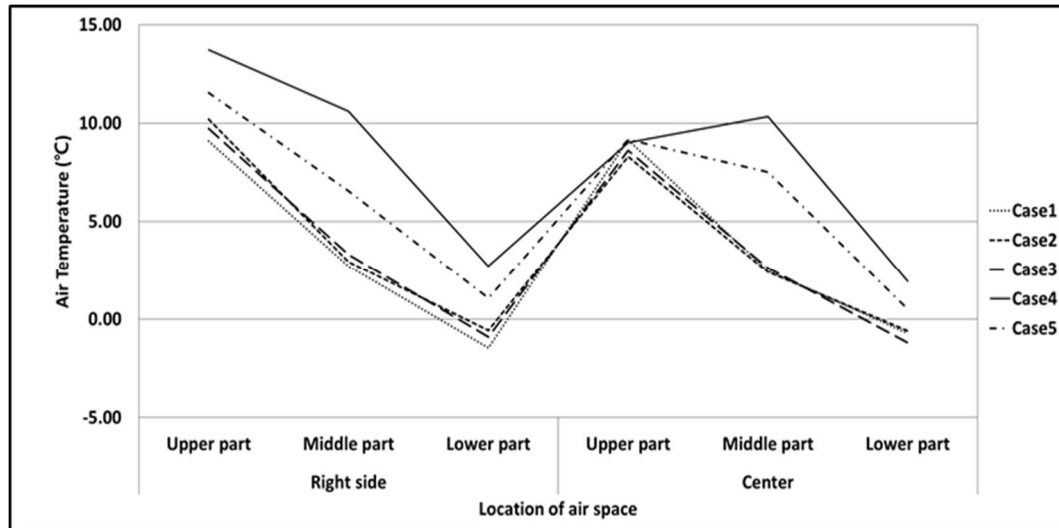


Figure 4: Air temperature in air space

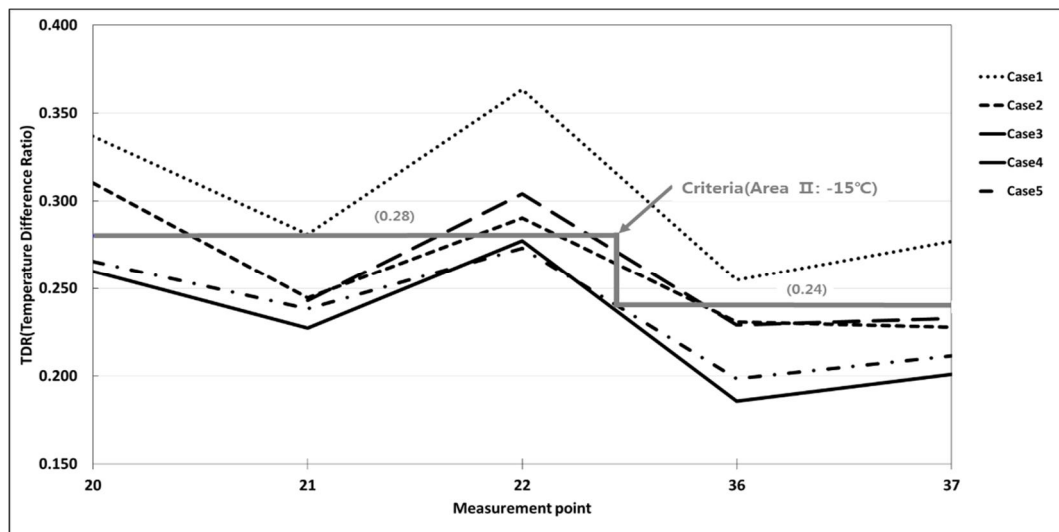


Figure 5: TDR of the inside window (parts in low thermal insulation, #4)

## 4. Result

Based on the experiment results of this study, it is found that the application of low-e glass to the outside window can increase the air temperature in air space and improve the condensation prevention performance of windows. The specific contents are as follows:

(1) According to the results of a full-scale performance test for the improvement of condensation prevention performance of double-glazing windows in common housing, only Case 4 (the location of low-e glass: the outside window) and Case 5 (the location of low-e glass: the outside and the inside windows) satisfied the requirements of TDR under the criteria of area II.

(2) As the location of low-e glass changed from the inside window to the outside window, the air temperature of air space rose remarkably, and not only the inside window but also the outside window was found to have the likelihood of an improvement of condensation prevention performance with an increase in the air temperature of air space.

(3) The condensation prevention performance of Case 4 turned out more excellent than that of Case 5, and both the inside window and the outside window was found to have the likelihood of both an improvement of condensation prevention performance and cost-saving.

## Acknowledgements

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# The Energy Loads According to Thermal Performance of Window Glazing

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## Abstract

Recently, efficient use of energy is more important in buildings. Window is the biggest part of heating and cooling energy loss on building facade. To predict thermal performance of the window systems generally is calculated based on the U-value of window glazing. However, there is a limit to predict the thermal performance of the window systems. Because the solar radiation is coming indoor through the window glass. An SHGC (Solar Heat Gain Coefficient) of window is a determinant of total energy of solar radiation coming indoor in heating and cooling loads. In this study, thermal performance was evaluated according to the U-value and SHGC of window glazing. As a result, this experiment analysed cooling energy consumption reduction effect by window glazing. And it is useful to select a good SHGC (Solar Heat Gain Coefficient) performance of window glazing in the office buildings.

**Keywords:** Energy Load, Thermal Performance, Window Glazing, SHGC (Solar heat gain coefficient), U-value (Thermal transmittance), VLT (Visible light transmittance)

# 1. Introduction

Windows are the parts with the largest heat loss among building envelopes and these parts influence up to approximately 40 % of heating and cooling energy. Since the ratio of area occupied by the windows in the building envelope as the preference of occupants such as the assessment of openness and design elements is increasing these days, it is expected that heat loss from the windows will increase gradually.

The thermal performance of windows is decided according to the performance of glass and frame, and especially glass significantly affects the inflow of radiant energy, so it is important to understand and apply the performance of glass properly according to the purpose of building and objective. If glass showing improper performance is applied, it may increase loss of heating and cooling energy in the building.

In this study, the energy simulation was performed in order to identify the influence of glass's thermal transmittance (U-value), solar heat gain coefficient (SHGC) and visible light transmittance (VLT) on the heating and cooling energy loads in the building.

# 2. Methodology

The performance evaluation was carried out through the execution of the experiment. In the experiment, the energy and environmental performance evaluation was carried out using a chamber where the performance evaluation was available in its own outdoor air environments. The elements for performance measurement through the experiment in this study are as shown in the following Table 1.

*Table 1: Performance verification elements of envelope system*

<i>Classification</i>	<i>Contents</i>	<i>Note</i>
<i>Characteristics of seasonal environments</i>	<i>Evaluation of environmental performance for summer and winter seasons</i>	-
<i>Characteristics of solar radiation</i>	<i>Evaluation of influence of solar radiation on the envelope system</i>	<i>Analysis of indoor and outdoor solar radiation</i>
<i>Characteristics of energy saving performance</i>	<i>Evaluation of energy saving performance according to the envelope system</i>	<i>Analysis of energy loads</i>
<i>Characteristics of surface temperature</i>	<i>The indoor and outdoor surface temperature of envelope system</i>	<i>Analysis of surface temperature</i>

The performance analysis procedures are as follows;

- 1) Performance evaluation of envelope system
  - Analysis elements: Outdoor and indoor environmental conditions, energy loads
  - Comparison and analysis of 3 CASE glazing
- 2) Performance evaluation of envelope system based on the measured experiment result

- Analysis of indoor temperature, transmission solar radiation, surface temperature, energy consumption
- Performance comparison and analysis of developed double glazing in comparison to the previous double glazing
- 3) Analysis of mock-up model information and actually measured meteorological data
  - Analysis of experimental chamber information for implementing the simulation model
  - Analysis and processing of outdoor environmental elements for producing meteorological data
- 4) Performance analysis of window glazing
  - evaluate the effects of double glazing based on the result of experiment measurement

### 3. The experimental chamber

The experimental chamber used in this study is located in Korea, and the experiment and measurement of up to 3 envelope systems are available. The surface of the experimental chamber used in the experiment except for glass part comes into contact with the monitoring room that collects the experiment result. In order to create actual environmental condition of the building, the lighting fixture and HVAC system are installed inside the Test Room, and the power outlet enabling the use of electricity is also installed. Also, the 1 meter-high plenum has been constructed.

The size of experimental chamber is 9.8 m wide and 7.0 m long, and the wall of the experiment chamber is produced in the sandwich panel made of rigid polyurethane foam (steel sheet 1.0 mm + rigid polyurethane foam 100 mm + steel sheet 1.0 mm). The specifications of all heating and cooling systems are same, and two systems in the monitoring room and one system in each Test Room are installed.

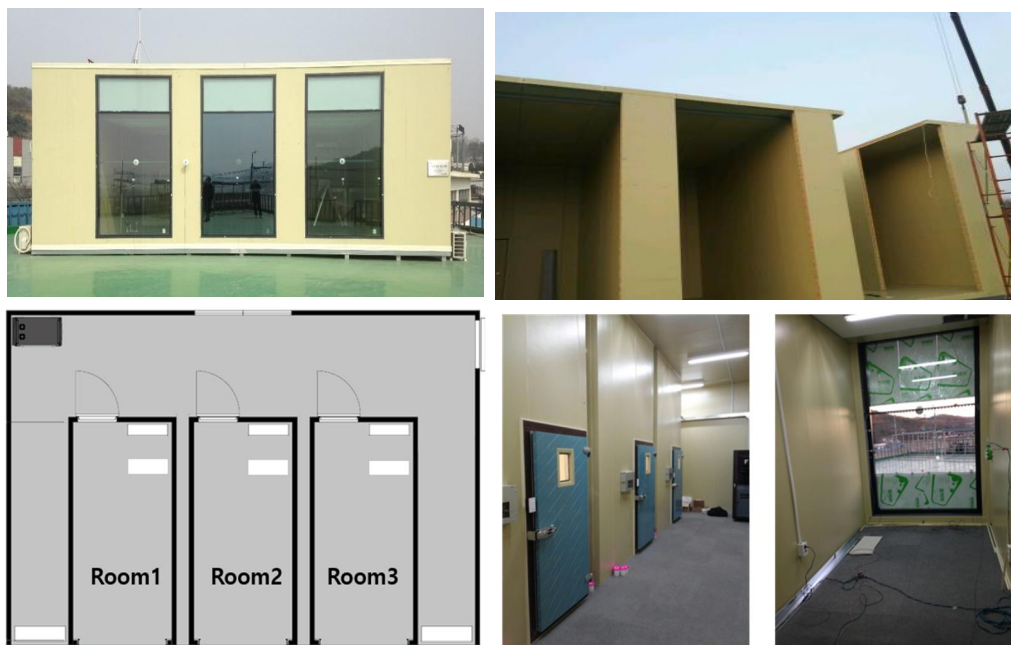


Figure 1: Outside/inside view of experiment chamber

Table 2: The specification of experimental chamber

Type		Details
Location		Paju-si, Gyeonggi-do, Korea
Airt		Full south aspect
Scale	Test Room	2.2 m * 4.5 m
	Window glazing	1.8 m * 3.8 m

### 3.1 Operation of experimental chamber

Air conditioning is available in three Test Rooms according to the outdoor environment and the set indoor temperature, and the measurement of indoor environments (temperature, humidity, illumination, air velocity) and energy consumption (power consumption of HVAC systems) according to the performance of envelope is possible. The inverter heating and cooling systems are installed for air conditioning so that temperature control is available, and the energy consumption of each Test Room can be collected accordingly.

### 3.2 Composition of measurement equipment

The heating and cooling systems that were operated separately were installed on three Test Rooms where the experiment was carried out, and the thermo-hygrometer and anemometer were installed on the air outlet. The surface temperature of each target envelope system for experiment was measured using a thermocouple inside, and the internal air temperature and humidity were measured through the thermo-hygrometer.

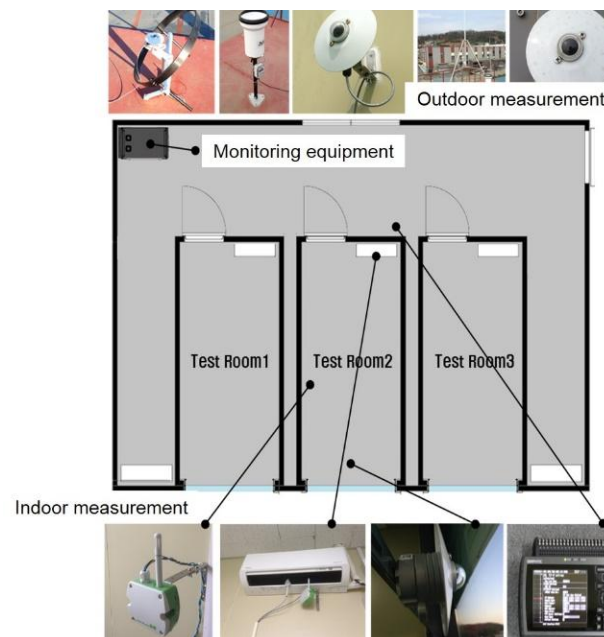


Figure 2: Measurement equipment

The surface temperature on the central part, edge and frame of the target envelope systems for measurement was measured, and the pyranometer was installed inside and outside the central part of glass. The pyranometer (global solar radiation and diffused solar radiation) and anemoscope/anemometer were installed on the roof of the chamber to measure meteorological data. Data measured from the experiment was recorded on the database of distribution box in the equipment room.

### 3.3 Experiment plan and method

In the experiment, two performance measurement experiments on the envelope system were carried out, and the performance of the selected experiment target was measured by combining various key technologies according to the period. The experiment target and the performance measurement period are as follows.

*Table 3: Experiment schedule and details*

<i>Classification</i>	<i>Period</i>	<i>Contents</i>
<i>Envelope system (double glazing)</i>	<i>Summer</i>	<i>Performance evaluation of Low-e coated double glazing according to the performance of U-value/SHGC</i>
	<i>Winter</i>	
	<i>Summer</i>	<i>Performance evaluation of glazing according to environment and operating condition change</i>

In the experiment, the level of influence from indoor environments and performance of the building were compared and analysed by carrying out the experiment and measurement of envelope system meeting the performance standards of envelope specified in domestic construction laws and the envelope system where the technology developed through the research was applied under the same conditions.

In this study, the envelope system was installed on the experimental chamber according to the plan shown above and the performance measurement experiment was carried out, and the performance evaluation was carried out based on the indoor environments and energy consumption according to changes such as summer and winter seasons, and operating conditions of building. The summary of experiment is as follows;

- Outdoor condition: Actual outdoor environments in the experiment area
- Measurement period: August 2014 ~ September 2015  
(Carry out the analysis of experiment result by selecting the period considered to represent the optimum weather conditions during each solar term)
- Set temperature: Varies according to the experiment condition
- Comparison and measurement elements for each experiment target
  - Set indoor temperature
  - Surface temperature of envelope system

- Comparison of internal vertical solar radiation
- Comparison of power consumption according to heating and cooling

## 4. Results

### 4.1 Performance of double glazing

The measurement details for the period satisfying the optimum conditions for each solar term during the experiment period during summer and winter seasons were utilized for the experiment result analysis, and the period used for the measurement result analysis is as shown in the following Table 4.

Table 4: Specification of glazing (1<sup>st</sup>)

Classification		Test Room 1			Test Room 2			Test Room 3		
Window glazing		Single Low-e double glazing			Triple Low-e double glazing			Single Low-e triple glazing		
Spec.	Glass 1 (Outside)	6 mm Low-e (#2)			6 mm Low-e (#2)			6 mm Low-e (#2)		
	Gap 1	12 mm Argon			16 mm Argon			12 mm Argon		
	Glass 2	6 mm Clear			6 mm Low-e (#4)			6 mm Low-e (#4)		
	Gap 2	-			-			12 mm Argon		
	Glass 3	-			-			6 mm Clear		
	Performance	U-value [W/m <sup>2</sup> K]	SHGC	VLT	U-value [W/m <sup>2</sup> K]	SHGC	VLT	U-value [W/m <sup>2</sup> K]	SHGC	VLT
		1.781	0.615	0.729	1.222	0.178	0.277	1.018	0.507	0.611

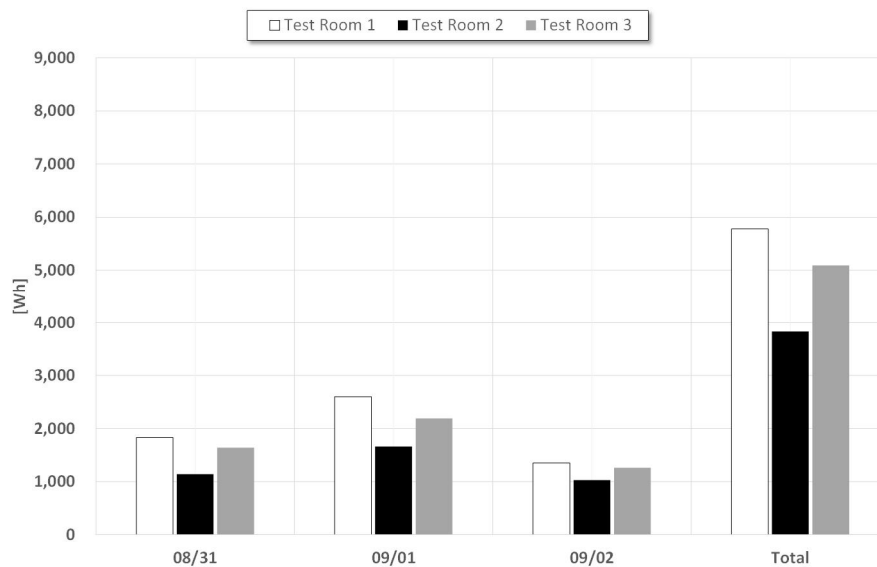
Table 5: Experiment conditions (1<sup>st</sup>)

Classification	Summer	Winter
Period	2014.08.31 ~ 2014.09.02	2015.01.10 ~ 2015.01.12
Heating and cooling time	08:00 ~ 18:00	
Set temperature	24 °C	
Measurement elements	- Meteorological elements: Global solar radiation, diffused solar radiation, vertical solar radiation, outdoor temperature, relative humidity, air volume, air velocity - Indoor environmental elements: Vertical solar radiation, indoor temperature, surface temperature, energy consumption	

The following figure and table show the energy consumption during the measurement period. The measurement result showed that the Triple Low-e double glazing (Test Room 2) was effective for saving energy during both summer and winter seasons. It was confirmed that Triple Low-e double glazing (Test Room 2) showed an approximately 33.7 % energy saving effects during summer season and an approximately 17.4 % energy saving effects during winter season in comparison to Single Low-e double glazing (Test Room 1). On the other hand, it was confirmed that Single Low-e triple glazing (Test Room 3) showed an approximately 11.9 % energy saving effects during summer season and an approximately 9.0 % energy saving effects during winter season in comparison to Single Low-e double glazing (Test Room 1).

*Table 6: Energy consumption (summer)*

<i>Classification</i>	<i>08/31</i>	<i>09/01</i>	<i>09/02</i>	<i>Total</i>	<i>Reduction Ratio (Compared to Test Room 1)</i>
<i>Test Room 1 [Wh]</i>	<i>1,830</i>	<i>2,600</i>	<i>1,350</i>	<i>5,780</i>	<i>-</i>
<i>Test Room 2 [Wh]</i>	<i>1,140</i>	<i>1,660</i>	<i>1,030</i>	<i>3,830</i>	<i>33.7</i>
<i>Test Room 3 [Wh]</i>	<i>1,640</i>	<i>2,190</i>	<i>1,260</i>	<i>5,090</i>	<i>11.9</i>



*Figure 3: Energy consumption (summer)*

*Table 7: Energy consumption (winter)*

<i>Classification</i>	<i>01/10</i>	<i>01/11</i>	<i>01/12</i>	<i>Total</i>	<i>Reduction Ratio (Compared to Test Room 1)</i>
<i>Test Room 1 [Wh]</i>	<i>2,770</i>	<i>2,560</i>	<i>2,870</i>	<i>8,200</i>	<i>-</i>
<i>Test Room 2 [Wh]</i>	<i>2,400</i>	<i>2,010</i>	<i>2,360</i>	<i>6,770</i>	<i>17.4</i>
<i>Test Room 3 [Wh]</i>	<i>2,530</i>	<i>2,290</i>	<i>2,640</i>	<i>7,460</i>	<i>9.0</i>

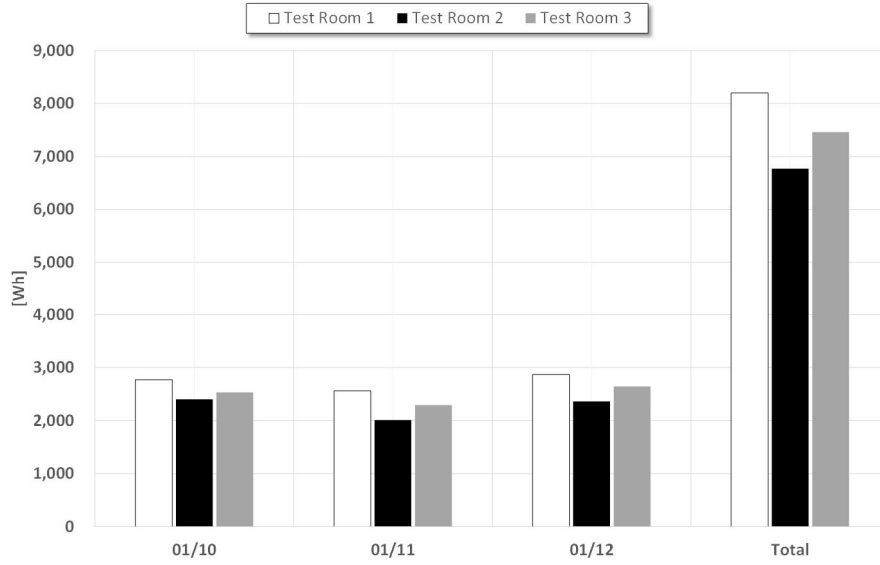


Figure 4: Energy consumption (winter)

## 4.2 Performance of double glazing according to the indoor operating condition

In order to analyse the performance characteristics of double glazing, the influence of experiment glass on the indoor environments and energy consumption according to operating condition change was evaluated. Especially, the performance to interrupt solar heat and save cooling energy was an important evaluation item so that the experiment measurement was carried out during the summer season. The specifications of applied double glazing and indoor operating condition are as follows.

Table 8: Specification of glazing (2<sup>nd</sup>)

Classification		Test Room 1			Test Room 2		
Window glazing		Single Low-e double glazing			Triple Low-e double glazing		
Spec.	Glass 1 (Outside)	6 mm Low-e (#2)			6 mm Low-e (#2)		
	Gap 1	12 mm Air			16 mm Argon		
	Glass 2	6 mm Low-e (#3)			6 mm Low-e (#4)		
	Gap 2	-			-		
	Glass 3	-			-		
	Performance	U-value [W/m <sup>2</sup> K]	SHGC	VLT	U-value [W/m <sup>2</sup> K]	SHGC	VLT
		1.876	0.589	0.686	1.222	0.178	0.277



Table 9: Experiment conditions (2<sup>nd</sup>)

Classification		Period	Cooling time	Temperature
CASE 1	Daytime Cooling	2015.08.27 ~ 2015.08.29	08:00 ~ 18:00	26 ℃
CASE 2	24-hour Cooling	2015.09.04 ~ 2015.09.06	24-hour	26 ℃

In CASE 1, the following figure and table show the energy consumption during the measurement period. The measurement result showed that the Triple Low-e double glazing (Test Room 2) was effective for saving energy. It was confirmed that Triple Low-e double glazing (Test Room 2) showed an approximately 40.3 % energy saving effects in comparison to Single Low-e double glazing (Test Room 1).

Table 10: Energy consumption (CASE 1)

Classification	08/27	08/28	08/29	Total	Reduction Ratio (Compared to Test Room 1)
Test Room 1 [Wh]	2,000	2,060	2,200	6,260	-
Test Room 2 [Wh]	1,200	1,220	1,320	3,740	40.3

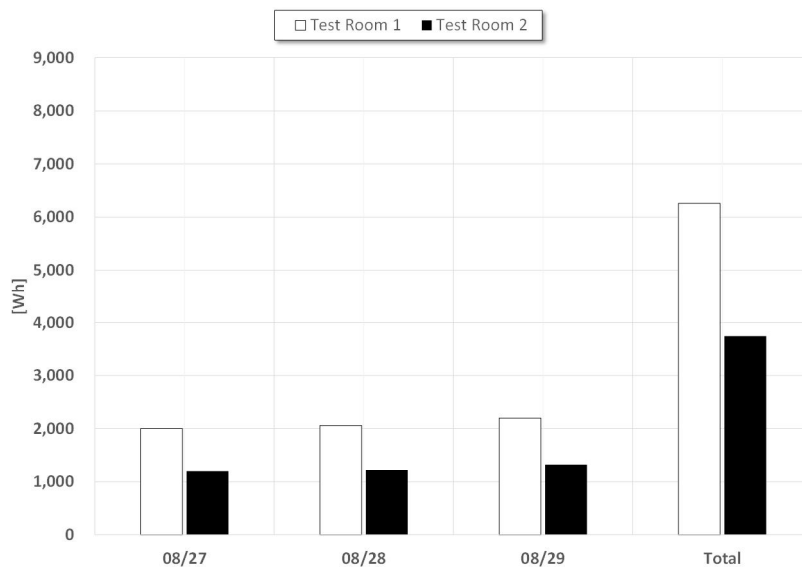


Figure 5: Energy consumption (CASE 1)

In CASE 2, the following figure and table show the energy consumption during the measurement period. The measurement result showed that the Triple Low-e double glazing (Test Room 2) was effective for saving energy just as CASE 1. It was confirmed that Triple Low-e double glazing (Test Room 2) showed an approximately 30.6 % energy saving effects in comparison to Single Low-e double glazing (Test Room 1).

Table 11: Energy consumption (CASE 2)

Classification	09/04	09/05	09/06	Total	Reduction Ratio (Compared to Test Room 1)
Test Room 1 [Wh]	2,880	690	1,560	5,130	-
Test Room 2 [Wh]	1,890	610	1,060	3,560	30.6

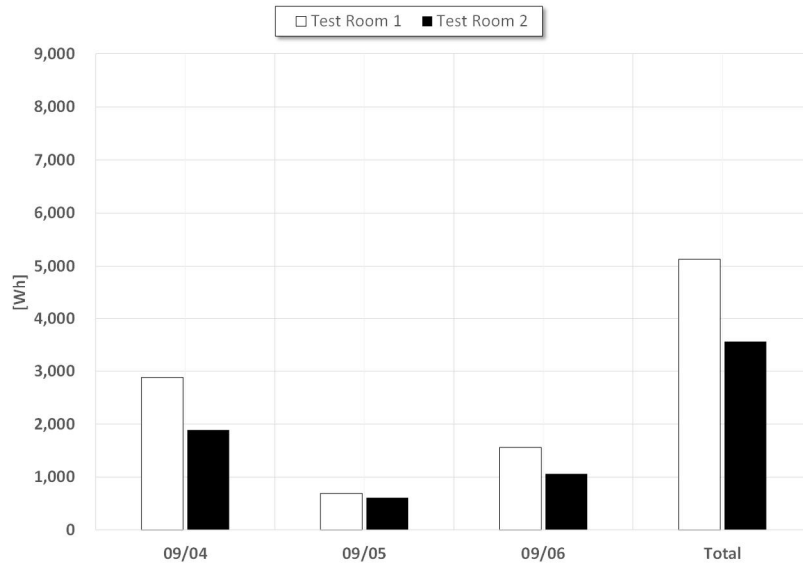


Figure 6: Energy consumption (CASE 2)

## 5. Conclusions

In this study, the experiment measurement comparing the performance of three types of double glazing in terms of indoor thermal environment and energy saving was carried out. And, energy consumption of window glazing was compared and analysed according to performances such as SHGC (Solar heat gain coefficient), U-value (Thermal transmittance), VLT (Visible light transmittance). The result of this study can summaries as below.

- (1) The result of experiment measurement showed that Triple Low-e double glazing (Test Room 2) was effective for saving heating and cooling energy in both summer and winter seasons. It is speculated that the biggest cause is an effect of SHGC (Solar Heat Gain Coefficient) of window glazing (Test Room 2).
- (2) Also, it showed an excellent performance to interrupt the effects from outside temperature and incoming solar radiation in summer season, especially.
- (3) In particular, it is useful to select a good SHGC (Solar Heat Gain Coefficient) performance of window glazing in the office buildings due to effect of energy saving for daytime cooling.

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# Energy regulations for housing and the performance gap

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Research for the Built Environment

## Abstract

The goals of energy saving and CO<sub>2</sub> reductions to create an energy neutral building stock seem only to be reached by strict and supportive governmental policies. In Europe the Energy Performance of Buildings Directive and the Energy Efficiency Directive are driving forces for Member States to develop and strengthen energy performance regulations both for new buildings (via building approval procedures) and the existing building stock (via energy performance certificates or labels). The effectiveness of these current governance instruments and their impact on actual CO<sub>2</sub> reductions are found to be inadequate for ensuring actual energy performance is achieved. To realize the very ambitious energy saving goals a radical rethink of regulatory systems and instruments is necessary. Building performance and the behaviour of the occupants is not well understood by the policymakers. Alternative forms of governance are needed which have more impact on the actual outcomes. Supportive governance to stimulate near zero renovations in combination with performance guarantees is a promising approach. Furthermore engagement with occupant practices and behaviours is needed. To ensure accurate outcomes-based governance a better understanding of building performance and behaviours of occupants must be incorporated.

**Keywords:** Building control, building regulations, energy performance, governance, housing stock, occupants

# 1. Introduction

Climate change mitigation is the most important driver for the ambitions to reduce the use of fossil fuels. There are also other reasons for implementing energy efficiency policies in the EU and its Member States. These include the wish to diminish the dependency on fuel imports, the increasing costs and the fact that fuel resources are limited as well as the impacts on public health. The European building sector is responsible for about 40% of the total primary energy consumption. To reduce this share, the European Commission (EC) has introduced the Energy Performance of Buildings Directive (EPBD) (2010/31/EC) and more recently the Energy Efficiency Directive (EED – 2012/27/EU). These frameworks require Member States to develop energy performance regulations for new buildings, a system of energy performance certificates for all existing buildings and policy programmes that support actions to reach specific goals (e.g. building only ‘Nearly Zero Energy Buildings (NZEB)’ by 2020 and realizing an almost carbon neutral building stock by 2050). Formulating ambitions and sharpening regulations are relatively easy to do. Technical solutions are currently available to realise the NZEB standard in building projects and an increasing number of NZEB projects are being built. However, substantial evidence exists that mainstream of building projects do not realize the expected energy performance in practice - the building performance gap. What is perhaps even more important in this respect is that the focus predominantly should be on the existing building stock. About 75% of the buildings that will comprise the European housing stock in 2050 has already been built today. Therefore, it is important to get insight in whether the energy performance certificates (EPCs) give reliable information or not. Many researchers have found evidence of the performance gap. This paper elaborates on this subject in next section. This is followed by reference to results of research by Guerra Santin (2009, 2010) focusing on the situation in newly built houses. The fourth section presents the findings of Majcen (2013a, 2013b, 2015) who studied in detail the relation between the energy labels (Energy Performance Certificates) and the actual energy use in dwellings. The fifth section discusses these findings in order to answer the main question: What could be adequate policies and regulatory tools to control the actual energy use in houses? The conclusions are presented in the final section. This paper is adapted from Visscher et al 2016.

## 2. Performance gap

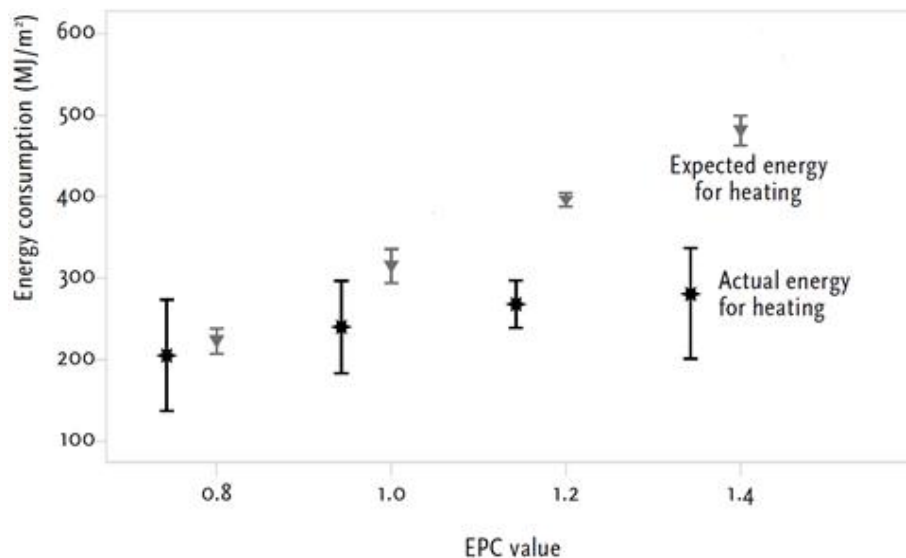
Building regulations can only partially influence the energy use in a building. The other significant influence is determined by the behaviour of the occupant. The design and materialisation of a building can give better conditions for comfortable temperatures and in multi-occupancy residential buildings the lighting in the communal areas and use of lifts, so these aspects are subject of the regulations. All other forms of energy use in dwellings, (e.g. plug loads - refrigerators, washing machines, computers and cooking appliances) are not controlled by building regulations but covered by other legislation. In general, for older buildings the energy demand for space heating and cooling is dominant. In newer buildings with a very high level of

insulation, the energy demand for appliances becomes dominant. Regulations focus on the design and in the best cases there is even some control on the performance of a building at the end of the construction process. However, after the building is occupied there is little if any control over the energy use. The energy calculation methods that are used or referred to in regulations are based on models and parameters of the performance of construction types and materials used and on the expected or modelled heating behaviour of the occupants. It is clear that all these models and assumptions do not accurately portray the actual energy use. This can be called the performance gap. The performance gap occurs for several different reasons: the built artefact does not match the design (substitutions and poor built quality), the mechanical services are not commissioned correctly, the inhabitants do not understand how to operate the building, the inhabitants' behaviour and practices are not as expected. Over the past 20 years numerous studies have compared the actual energy use with the expected or modelled energy use (Branco, Lachal, Gallinelli and Weber 2004; Cayre, Allibe, Laurent and Osso 2009; Sorrell, Dimitropoulos and Sommerville, 2009; Gram-Hanssen, 2010). The general pattern that follows from these studies is that for dwellings with a good (theoretical) energy performance the actual energy use in general is higher than modelled. For the dwellings with a bad (theoretical) performance, the actual energy use is lower. There are various explanations for these findings. For the presumed good performance buildings it is a combination of under performance of the building due to design and construction faults and changed behaviour of the occupants. This is partly the rebound effect (Berkhout et al. 2000; Galvin, 2015): if the conditions improve and the inhabitants think that the building is more energy efficient, they become less careful in their energy use behaviour (e.g. they use higher temperature settings, wear thinner clothing and operate the heating for longer periods). For the 'bad' performing buildings there is also evidence that the quality of the building could be under estimated. The U-values of solid walls in England were under estimated. Solid walls had been assumed to have U-value of 2.1 W/m<sup>2</sup>K, however recent research has shown a value in the range of 1.6 W/m<sup>2</sup>K (Li et al., 2015). Rasooli et al. (2016) found similar results in a study in the Netherlands. In addition to this there is large impact by the behaviour of the occupants. The models assume an average heating of the whole building, however in poorly insulated buildings the occupants are frugal and use heat sparingly, they also tend to heat only the spaces that they actually use.

### **3. Energy performances of new dwellings in practice**

In 1995 energy performance regulation for space heating and cooling of newly built constructions were introduced in the Netherlands. The regulation consists of a standard (norm) that prescribes the calculation method which is called the Energy Performance Norm. The standard results in a non-dimensional figure called the Energy Performance Coefficient. Every few years the level of this Energy Performance Coefficient was decreased, representing a lower energy use demand for building-related energy use. In 2021 this Energy Performance Coefficient will be on the level of nearly energy neutral according to the EPBD. Since the introduction of the energy performance regulation there has been little assessment of the regulation's effect on the actual energy use in the houses. Two studies found no statistical correlation between the Energy Performance Coefficient level and the actual energy use per dwelling or per m<sup>2</sup>. Guerra Santin (2009, 2010) compared the actual and expected energy consumptions for 313 Dutch dwellings, built after 1996. The method

included an analysis of the original energy performance calculations that were submitted to the municipality as part of the building permit application, a detailed questionnaire and some day-to-day occupant diaries. These combined approaches generated very detailed and accurate data of the (intended) physical quality of the dwellings and installations, about the actual energy use (from the energy bills) and of the households and their behaviour. The dwellings were categorised according to their Energy Performance Coefficient. Due to the relatively small sample size, the differences between the actual heating energy of buildings with different Energy Performance Coefficient values were insignificant. Nonetheless the average consumption was consistently lower in buildings with lower Energy Performance Coefficient, but not nearly as low as expected. In this sample, it was found that the increased level of the energy performance had very little effect on the actual energy use. Guerra Santin found that building characteristics (including heating and ventilation installations) were responsible for 19% - 23% of the variation in energy used in the recently built building stock.

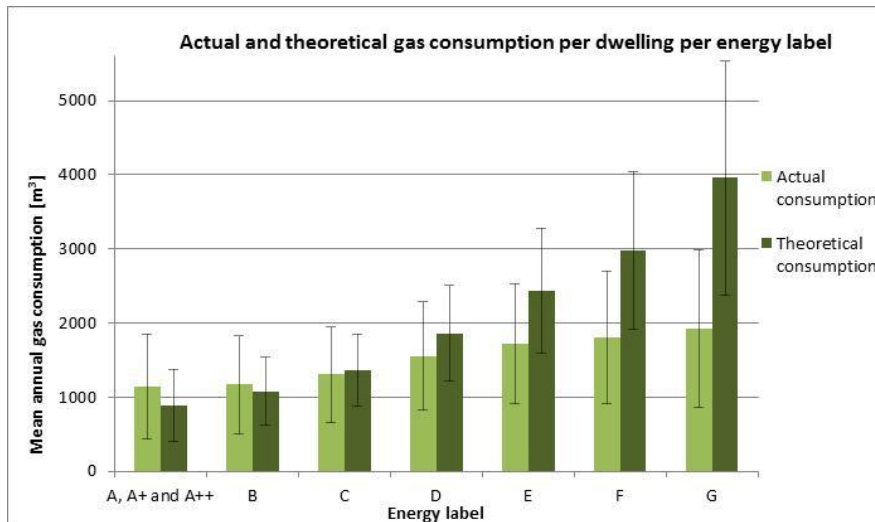


*Figure 1 Mean and 95% confidence interval for the actual energy consumption (MJ/m<sup>2</sup>) and expected energy for heating (MJ/m<sup>2</sup>) per EPC value Source: Guerra Santin, 2009*

Taking into account the above findings, it is doubtful whether further tightening of the energy performance regulations will lead to improvements in actual outcomes. Other and more efficient solutions exist to decrease the actual energy consumption of newly built dwellings. Important ingredients of the solution are: ensuring that appliances and installation are correctly installed, monitoring the calculated performances in practice; enlarging the know-how and skills of building professionals and creating an effective and efficient building control and enforcement process. Monitoring the actual performance in the completed building becomes more important.

## 4. Actual versus calculated energy use: existing dwellings

The largest energy saving potential is in the existing building stock. New dwellings add about one per cent per year to the housing stock in Europe. The most important policy tool required by the EPBD in the European Member States is the issuing of Energy Performance Certificates (or EPCs). These EPCs give a hypothecated indication of the required energy to provide a certain average temperature in the building and depend on physical characteristics of the building. The certificate has no mandatory implications in the sense that owners could be forced to improve their buildings to certain levels. Nonetheless it is a crucial instrument for benchmarking and formulating policy goals. Building owners in all EU Member States have to obtain an EPC for a building at the moment it is sold or rented out. This is not yet current practice everywhere, mostly due to lack of enforcement. This especially applies to the private housing stock. In a research project by Majcen (2013a, 2013b) the actual energy consumption was compared with the theoretical use according to the EPC's (see figure 2).



*Figure 2 Actual and theoretical gas consumption in Dutch dwellings - per m2 dwelling area,*

*Source: Majcen et al., 2013a*

This research was based on the Dutch energy labels issued in 2010 - a total of over 340,000 cases with 43 variables (regarding building location and technical characteristics, the properties of the label itself etc.). This data set was derived from the publicly available database of the EPCs. This data was, on the basis of the addresses of the households, linked to actual energy use data. The energy data was provided by the CBS (Statistics Netherlands), which collected this data from the energy companies. The combined data file was then cleaned by deleting incomplete or obvious incorrect EPCs. This resulted in 193,856 usable cases. This still large sample proved to be representative for all housing types and energy label classes.



To understand how the energy label relates to the discrepancies, the gas and electricity consumption in various label categories were examined and analysed. The actual and theoretical gas use per dwelling was compared and then analysed per m<sup>2</sup> of dwelling (figure 5). Little difference exists between the actual and theoretical energy use calculated per dwellings and per m<sup>2</sup>, except the difference in actual gas use between label A and label B. At the level of individual dwellings, the actual consumption was identical, but at the level of m<sup>2</sup> the dwellings in category A use less gas than dwellings in category B. This may relate directly to the fact that dwellings in label category A were found to be considerably larger than all other dwellings. From these figures it is clear that although better labels lead to higher actual gas consumption, there is a clear difference between the mean theoretical and mean actual gas consumption for each label. For the most energy-efficient categories (A, A+ and A++) and for category B, Figure 5 shows that the theoretical calculation underestimated the actual annual gas consumption. This is in contrast to the rest of the categories for which the theoretical calculation largely overestimated the actual annual gas consumption. This research indicates that the energy label has some predictive power for the actual gas consumption. However, according to the labels, dwellings in a better label category should use on average significantly less gas than dwellings with poorer labels, which is not the case.

## **5. Discussion: alternative policies and regulations to control energy use in dwellings**

It is evident that current general regulatory instruments can only partly influence the actual energy use in houses. Regulations only address the energy use that is (partly) related to the physical condition of the building (as appliances and users are outside their scope). However, there needs to be a shift in focus to ascertain the 'as built' quality. For example, nearly zero energy buildings would require airtightness tests and infrared scans (to highlight any thermal bridging). The adequate functioning and the capacity of ventilation systems also needs testing. A differentiation is needed in regulations to account for in-use performance. This is because any mistake during the construction process will lead to a reduction of the minimum required performance and efficiency, thereby negatively influencing the energy demand. Analysing the actual energy use compared to the indications of the EPC's gives a clear insight in the under prediction of the use in houses with good labels and large over predictions in the house with bad labels. This also leads to wrong assumptions of payback times of the investments. Strict regulations for new houses and retrofits will improve the physical performance of the building, but have a limited influence on the actual energy use. Given the limitations of current building regulations, what other forms of governance could be used to reduce the domestic energy use and CO<sub>2</sub> emissions?

An innovative approach for deep energy renovations to nearly zero in the Netherlands is called the Net Zero Energy Renovation concept. Houses from the 1960s and 70s with a poor energy performance are retrofitted with a new highly insulated skin, air source heat pump heating and PV panels. The renovation process is highly industrialised and the renovation time is limited to two weeks or less. Currently these deep retrofits are mostly done to social housing (houses from housing associations). A change in governance has been influential. A new law allows the housing

associations to increase the rent by the cost of the average energy bill. After the retrofit, the tenants only pay a higher rent but no energy bill at all, provided their actual energy use within a prescribed limit. This only works if the theoretical estimations of the actual energy demand are correct. Concurrent with this is the development of a new contractual obligation: an energy performance guarantee by the construction company. This is a kind of Energy Performance Contract where the owner occupant pays for the retrofit and gets a guarantee for a zero energy bill. In principle, the increase in rent should be offset by not having to pay an energy bill. The first evaluations are appearing now (Energiesprong, 2016), but they are only based on just a few cases. Some of the occupants are satisfied, but others are dissatisfied because the energy demand concept is below their expectation. It is based on lower indoor temperatures (20°C), short times for showering and an energy sober life style. If these occupants exceed the allowed level of energy use, then they have to pay extra for it. There will be much variation among users but a reasonable baseline for normal energy demand may act as a positive influence on behaviours and practices. The near zero concept of houses will help to reduce the variation, but still there will remain some variation and really zero can't be guaranteed. This suggests that in addition to the physical aspects of creating a near zero building, there are also social aspects relating to energy demand that need to be addressed. However, the overall impact on energy and CO<sub>2</sub> reductions from these buildings (and the underlying regime that created them) has been significant. Energy Performance Guarantees are basically a voluntary development by market parties. Until now, the underpinning governance has been supportive. The initiative was developed by an agency (Energiesprong which translates as 'Energy jump') and financially supported by the government. Recently the support programme has stopped and the expectation now is that the market should further develop it.

The policies for the existing stock are largely based on the EPC's. In the first place home owners and occupants are informed about the energy performance of a dwelling. This can influence buyers and should stimulate owners to renovate their homes. Often the incentive schemes use the concept of payback times. This is based on the argument why not invest (e.g. €10,000) if this can be earned back in 10 years by a lower energy bill? The insights presented in this paper show that this hardly works for renovations on the skin of a building to reduce the heating demand. There is a slight reduction of energy use, but the comfort level increases (higher temperatures). To have a real impact on savings the retrofit should go to the level of near zero.

Another investment strategy is in on-site renewable energy generation. This is independent from the occupant behaviour. However, it is dependent on the energy price. The drastic reduction of the oil price in 2015 illustrates this. The feed-in tariffs for electricity are set by governments and are also unpredictable. In the Netherlands, homeowners can yearly feed in 3000 kW for the same price as the price they have to pay for electricity, which includes 75% taxes. This arrangement makes it very profitable to buy PV-panels. However the government is now considering a change to this regulation in 2020. This shows that taxes and incentives can be a very strong governance tool.

Murphy (2012, 2014) investigated how owner-occupiers respond to various kinds of incentives by the National and Local Dutch governments. Most of these incentives were connected to EPC's and advise on making houses more energy efficient. These forms of governance had only modest

success. The willingness to invest in energy renovations is still limited, especially due to many uncertainties about the reliability of the contractors and the actual energy savings as found by Galvin (2014) in Germany.

Other forms of information about actual energy use seem more promising. Quarterly energy use reports of the energy companies give better insights and are related to previous year's corresponding quarter and to neighbours' energy patterns. Smart meters are nowadays installed on a large scale. In a few years most homes will have one. At the same time energy management displays are more and more used. Smart meters and these displays can be seen and used on smart phones. The insight will increase, but is this enough to stimulate energy saving behaviour including renovation investments? Studies (e.g. Darby, 2008) about the potential of giving accurate feedback to users about their behavior indicate that 5 to 10 % savings might be achieved.

## 6. Conclusion

To improve this situation for new buildings it has to be assured that constructions and installations are installed properly and in such way that they are not vulnerable for unpredictable or misuse by the occupants. This will set demands on both the construction industry and the control / enforcement process. The public building regulations and enforcement systems will continue to have an important role. The improvement of the existing building stock forms a big challenge. The potential energy savings are large, but the barriers to overcome are also high. Actual energy savings in renovated dwellings stay behind expectations due to rebound effects and lower than expected energy use in the old dwellings. Many owners believe that the benefits of the measures do not outweigh the costs. For all kind of governance policies and instruments, an accurate insight into the actual performances of buildings, actual energy use, behaviour and preferences of occupants will be essential. The unexplored territory for governance is how occupants' expectations, behaviours and social practices in using energy can be changed. Rational, economic incentives do not appear to be convincing or effective. Other levers, narratives and instruments are needed to monitor and encourage a frugal approach to energy demand and its management. To ensure the success of governance strategies and instruments, the support and engagement with occupants will have a vital role. This represents a new area for (national and municipal) governments and the construction supply side. For the latter, it will necessitate new forms of engagement with occupants to demonstrate optimised use and new social practices, as well as ensuring that energy performance guarantees deliver. The creation of positive feedback loops for inhabitants seems essential.

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# Are building regulatory systems in European countries climate proof?

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## Abstract

Demands on the energy performance of new and existing buildings hold a prominent place in the regulations of all European countries. The influence of EU policy goals and contents of EU Directives reverberate strongly in the energy regulations. Goals set by the European Union are that all newly built constructions must have a zero energy level by 2020 and that the total building stock must be energy neutral by 2050. The Energy Performance of Buildings Directive and the Energy Efficiency Directive are designed to give Member States the regulatory tools to develop and strengthen energy performance regulations. There are indications that the current (energy) regulations alone are inadequate to realize the energy saving goals set by the EU and its Member States. The goals can only be reached by more strict and supportive governmental regulations. That does not only mean formulating more stringent demands. It also poses new challenges to the way the construction process is organized and the regulations are enforced and the roles and responsibilities of constructors (building and installation companies). In the quality control procedures focus should be put on the quality of the building as it is built and preferably as it is going to be used. The question is if current quality control frameworks are organized adequately in European countries to meet these demands. To give a beginning of an answer to this question we look at the regulatory systems of seven European countries (England & Wales, Ireland, Germany, France, the Netherlands, Norway, and Sweden) where private building professionals already play a dominant role in the quality control process. The paper zooms in on the robustness and focus of the quality control process and the demands that are made on building and installation companies with respect to meeting the quality demands. It appears that current building regulatory systems are not yet geared completely with the future demands.

**Keywords:** building regulations, quality control, European Union, housing quality

## 1. Introduction

Traditionally quality control of construction work in Europe has been a governmental responsibility. In most European countries local authority building control has been issuing

planning or building permits and were responsible for plan approval, site-inspections and checks on completion of constructions. During the last decades however these building control tasks have been outsourced more and more to private parties. The main driving force behind this development has been the wish of governments to deregulate. The shift of responsibilities to private parties should not only improve the quality of construction works but it could also streamline administrative procedures and processes. In the eyes of the policymakers this leads to a win-win situation: less regulation, leading to a qualitative better building stock through optimised (cheaper and faster) quality control procedures. It is exactly because of these reasons that the Dutch government is on the brink changing its quality control system of constructions towards a more private model (MBZK, 2015). In the Netherlands the discussion to change the quality control system has been going on for many years. The dominant line of policy of subsequent governments has been “privatise if possible and keep it public when necessary”.

Simultaneously with the strong wish to deregulate, new quality goals emerged that require regulatory governmental intervention. The reduction of energy use and environmental impact of construction have been the most important new policy goals the last decades. The European Union and its Member States have implemented regulations and enforcement schemes that should ensure very energy efficient new buildings and have introduced instruments to improve the energy performance of the existing building stock. On a European level the Energy Performance of Buildings Directive, the EPBD (2010/31/EC) and the Energy Efficiency Directive (EED – 2012/27/EU) have been the dominant frameworks for the Member States to fit in their national regulations. So although the general deregulation trend in Europe has led to less governmental intervention in the building sector, in the field of energy efficiency the number of regulations has increased and became more stringent.

Recent studies show that the (energy) regulations are probably inadequate to realize the energy saving goals set by the EU and its Member States (summarized in Visscher et al, 2016). To reach the goals, more strict and supportive governmental regulations are needed. That does not only mean formulating more stern demands. It also poses new challenges to the way the quality control process of constructions is organized and the regulations are enforced. The roles and responsibilities of (private) quality controllers and builders are an essential part of this. This paper explores if the regulations and the quality control processes in the ‘average’ European building regulatory system are fit for the task that lies ahead. Section 2 focusses first on the research project(s) the paper is based upon. The subsequent section 3 characterises the essentials of the systems in England & Wales, Ireland, Germany, France, Norway, Sweden and the Netherlands. In the closing sections 3 and 4 the results are discussed and the main conclusions are drawn.

## **2. Research approach**

For many years OTB – Research for the Built Environment, Delft University of Technology, has been involved in studying alternative visions on building regulatory systems in international comparative projects. Recently we have been involved in a study for the DG Internal Market to (Ecorys and Delft University of Technology, 2015). For the Dutch government we recently compared the proposed Dutch quality control system with those in some selected European



countries: England and Wales, France, Germany, Ireland, Norway and Sweden. In these countries the roles, tasks and responsibilities were analysed of public and private parties in assuring and guaranteeing the technical quality of construction works. Starting point was our existing dataset on building regulatory systems in Europe. Additional and updated information about the quality control systems was inventoried via desktop research. Relevant regulatory documents and other sources were analysed. The project started in the fall of 2015 and was finished in the spring of 2016 (Meijer et al, 2016). Within the boundaries of this paper the highlights of the research are presented.

### **3. Outline of the control systems of other countries**

This section summarises the research results for the seven European countries. Attention is paid to the nature of the quality control and the roles and responsibilities of the building professionals. Focus lies on the quality control of the technical demands. In all countries only municipalities can grant planning permission for the construction or modifications of new and existing buildings.

#### **3.1 England & Wales**

Minor construction work in England & Wales is exempt from technical building control. For the construction of relatively simple work the application of a building notice is sufficient. All other construction plans are subject to a quality control procedure. For the technical quality control of these plans, applicants can choose between local authority building control (LABC) or a private Approved Inspector. This dual quality control system has been in operation for more than 30 years. Approved Inspectors have to be certified and registered before they can act. There are no legal obligations concerning the way quality control should take place (e.g. concerning methods and giving an account of the control results). Nonetheless both public, as well as private controllers, have voluntarily committed themselves to the Building Control Performance Standards. These standards give guidelines how qualitative good building control should be performed (DCLG, website). The quality control process has a clear beginning and ending. LABC has to give building approval and issues a completion certificate at the end of the procedure. Approved Inspectors have to inform LABC that they are involved of the quality control of a construction at the begin and the end of the process (Meijer et al, 2016). Builders have to comply with the general rules concerning materials and workmanship. There are no general recognition or certification schemes for contractors or builders. However specialist installers can join a Competent Person Scheme. When recognised or certified (depending on education and practical experience) these installers can self-certify certain types of building work (e.g. glazing, heating systems). For these works building regulations approval is not needed. It is assumed that the work meets the requirements (Planning Portal, website). In practice many installations are being placed by these competent persons. Although there is no certainty that all these competent persons deliver adequate work, the certification framework in which they have to operate give certain basic assurances. At least their workmanship, capabilities and experiences have been tested before they are going to operate in practice. In general all parties responsible for a construction project (e.g.

owner/applicant, advisor, designer, builder or installer) must ensure that the work complies with all applicable requirements of the Building Regulations. Indemnity and warranty insurance schemes should protect the building owner for financial risk in case of defects and failures. There are no regulations that apply to a post occupancy testing of for instance if the regulations are being met. Between 2007 and 2010 owners had to provide a Home information Package before a property in England and Wales could be put on the open market for sale. This requirement has been suspended from May 2010 on and was formally repealed in the beginning of 2012. As in all other Member States EU legislation still requires building owners to provide an Energy Performance Certificate (or energy label) at the moment of a transaction.

### **3.2 France**

For technical control a public-private construction supervision system has been in operation in France for almost forty years. Three categories of construction works are distinguished. Renovation activities and small risk-free works are exempt from any control procedure. Simple building activities (up to a certain floor area) have to be reported to the municipality. Once the work is finished the municipality has to be notified, after which a completion certificate will be issued (Meijer et al, 2016). All other construction need a building permit and are eligible for a regular procedure. The complexity of the plan defines the quality control procedure. For relative uncomplicated works (like a house) a registered architect has to declare that the plan meets the regulatory demands. When the building is completed a notification has to be sent to the municipality before it can be taken into use. In practice these works are hardly being controlled during construction either by municipalities or private controllers (Deman, 2013). For complex construction works with a higher risk quality control by private control organisations is obligatory. Control starts in the phase of plan approval and continues until completion. After plan approval the control organisation has to deliver an initial technical report with his findings. Before construction starts a control or inspection plan has to be drawn up. Private controllers are legally liable to control the structural safety and the safety of persons. Site inspections are held at random. After completion the private controller has to deliver an end report on the technical control. Public and high-rise buildings must have a user permit before they can be used (MLHD, website). The private control organisation has to be certified and accredited and must be independent of the applicant/building owner. Organisations can be certified for various control scopes (e.g. all regulations, only fire safety regulations, regulations for installations etc.). A decisive factor behind this system is the French insurance and guarantee system for building works (Meijer et al, 2016). The relevant law (dating from 1978) dictates that every building professional involved with a construction project must have appropriate guarantee insurances (e.g. covering professional indemnity). Builders and contractors have to be registered otherwise there is no certainty that they can meet the guarantee provisions.

### **3.3 Germany**

To map the German situation we focussed on the regulation of North Rhine Westphalia. The German model can be best described as being a mix between public and private quality control. Municipalities are formally responsible for issuing the (building and completion) permits and the

quality control procedure. Recognised or registered building professionals however play an important role in the system. First of all a certified and registered architect and/or structural engineer must submit the permit application and usually takes care of plan approval. In addition – depending of the construction type and control scope – a state recognised expert (*Prüfsachverständige*) must be involved in the quality control process. State recognised experts have to be independent and comply with strict demands on education and practical experience (Building Code of NRW, 2015). Procedure wise Germany distinguishes construction works that are exempt from building control, works that must follow a ‘simplified’ procedure and works that are eligible for the regular permit procedure. Many minor construction works are exempt from building control. If there is a zoning plan in place dwellings of a medium or lower height could also be built without a building permission. Beforehand though evidence must be delivered to the municipality (certified by the architect and the state recognised expert) that the building plan meets the essential demands. The simple permit procedure applies to the construction of low rise residential buildings and other low risk buildings. Local building control does not check plans if designers certify that they comply with the building regulations. The structural design must be calculated by a qualified structural engineer and his design must be proofed by a state recognised expert. No completion certificate is being issued. The regular building permit procedure applies to the remaining construction works. The building application (and the supporting documents) must be signed by a certified architect or engineer. Normally a state recognised expert verifies compliance with the technical requirements (especially structural stability and fire safety). For the construction phase a contractor and a – independent- site manager has to be appointed. Both the builders as the other building professionals have to meet statutory insurance requirements regarding liability. During construction, building control is exercised by local building control and the site manager. Building authorities usually delegate site inspections on structural stability to a state recognised expert. The completion of the shell and the completion of the building have to be reported to the local building control authorities so it can be checked. If satisfied the local authority issue a completion certificate. (Meijer et al, 2016).

### **3.4 Ireland**

Ireland has recently (2014) changed its system to an almost entirely private system of quality control. In the new system competent private building professionals are responsible for the quality control of construction works. The system includes all kinds of new responsibilities and roles. Applicants for building approval must submit a Commencement Notice and ensure themselves that supervision during construction is carried out by a certified independent party: an Assigned Certifier. Some (simple) works are exempt from this obligation. This applies to construction works that do not need a planning permission or a fire safety certificate, like regular maintenance activities and or the construction of small extensions. In all other cases the applicant or building owner has to submit a Commencement Notice. Besides the inclusion of a certificate of design compliance, proof must be delivered that an Assigned Certifier is going to inspect and certify the works and a builder has been hired to carry out the works. Furthermore the certifier and the builder must declare that they will meet the regulations. Finally the Commencement Notice must be accompanied by an inspection notification framework and an inspection plan. After completion of the project, both the certifier as the builder must certify that the completed construction

complies with the demands of the Building Regulations (DECLG, 2014). Shortly after the new regulations came in to force, it came apparent that for the construction of one-off dwellings and extensions on existing houses, the costs of quality control were highly disproportionate. This has led to an amendment to the system. The mandatory requirement for statutory certificates of compliance for these constructions was removed. Owners and self-builders have the choice to opt-out of the statutory certification and are allowed to demonstrate by other means that the work is going to meet the demands. At the same time the government announced the development of a new local authority quality control process for single dwellings and residential and commercial buildings (Meijer et al, 2016). The effects of this change (on the number of applications or the construction quality) is yet unknown. For building professionals inclusion on statutory registers is the primary means of establishing competency. For architects and engineers these registers already are in operation. The register for builders should be in place shortly. Furthermore building professionals must ensure that they are adequately covered for liabilities (DECGL, website).

### **3.5 Netherlands**

In April 2016 the new law on Quality Assurance of buildings has been sent to the Dutch Parliament (MBZK, 2015). This law will change the quality control system of construction work in the Netherlands fundamentally. All control activities on compliance with the technical building regulations will be transferred from public authorities to private parties. In the new system the list of exemptions containing the risk-free construction works also will be extended. Besides that a new category 'Technical control free construction works' will be introduced. These are the same construction works as the exemptions, only difference is that these works have to get planning permission. All other construction works will be classified in three groups according to their complexity and possible consequences in case of failure. Class 1 contains for instance one family housing. Hospitals and high rise buildings are assigned to class 3. The technical quality control of these construction works will be carried out by private parties. An independent Admission Organisation is going to assess and recognise these private quality controllers and their quality control instruments. Municipalities stay responsible for checking planning and aesthetic issues. In the new system an applicant has to notify the municipality about his plans and the way quality control is going to be arranged. The appointed private controller carries out plan approval and makes an inspection plan and takes care of the control during the construction phase. At the end of the process the quality controller declares that the building meets the technical demands (IBK, 2014) and a completion file has to be delivered to the owner or applicant. To strengthen the position of the 'building consumers' the liability of builders (e.g. for hidden faults) will be sharpened in the Civil Code. A decade ago the initiative was taken by the government to introduce a Building File. This document should describe the condition of the building in relation to the building requirements, should help consumers to make their choice between buildings, and could function as a manual for use and maintenance. Although the Dutch government welcomed the idea, the concept did not get enough support at that time of the most important interest groups of the building sector. In the new system a completion file has to be delivered at the end of the quality control process. This could bring the Building File concept back to life.

### **3.6 Norway**

In the 1990's Norway (1997) changed its public quality control system drastically. The new system was largely based on self-certification by approved building professionals (architects, engineers and builders). These enterprises could self-certify their own construction works and that of others. In practice it quickly appeared that this new model proved to be highly ineffective. The main problems were that self-certification by building professionals was inadequate and that local authorities failed to supervise the private parties (World Bank Group, 2013). From 2012 on a new regulatory framework has come into force. The essence of the system (self-certification) has not changed, but the checks and balances to assure the quality of the quality control process have been sharpened considerably. The demands and supervision on both quality as independence of control have become stricter. Building professionals have to meet demands on education and practical experience. Norway makes a distinction between construction works that need a permit and risk-free works that are exempt from a permit and a procedure. The other projects require an application and building permission. The other construction works are eligible for the quality control procedure (KoRD, 2015). All parties involved (applicants, designers, engineers and builders) have to be approved by the central government as a responsible enterprise. All roles have to be filed in properly before the authority issues a building permission (DiBK, website). The process starts with an obligatory preliminary consultation meeting where the parties involved decide about an inspection plan. This inspection plan is used during the construction and completion phase. For critical building elements (e.g. structural components, fire safety, energy efficiency and the building envelope) in more complex constructions independent private control is obligatory (Meijer et al, 2016). At the end of the construction process the controller/applicant has to make a completion report and file an application to the municipality for a completion certificate. At completion the applicant and builder has to supply the user or occupant of the building with an user and maintenance manual of the building. A last interesting feature in Norway is that local authorities have the statutory duty to make a strategic policy plan about building control. Certain elements have to be addressed in that plan, like prioritising the supervision and control on certain areas. Those priority areas could be certain construction types or certain technical requirements. The national ministry has the right to give the municipalities orders to set these priorities. In the period 2013-2014 the local authorities had, by ministerial order, to check if all construction projects carried out in their municipality met the minimum energy performance requirements.

### **3.7 Sweden**

The general rule in Sweden is that for a work needing building approval there must be at least one private person/party involved that controls the quality during construction. The demands on the private controller are established in the Law of Building and Planning 2010. The quality controllers must be certified before they can operate in practice (Boverket, website). Sweden also recognises various categories of construction works. Besides construction works that are exempt, Sweden distinguishes a category works that in principle is exempt, but mainly because of planning reasons has to be reported to the municipality before construction can start. For the construction and renovation/adaption of single single-family and semi-detached houses, the requirements are

also generally less stringent (Deman, 2013). When private quality control is necessary an inspection plan has to be made and a technical meeting has to be organised. All parties involved must attend this technical meeting. Only if the municipal building committee agrees with the inspection plan the building permit is issued. The municipality building committee controls the essential elements (structural and fire safety, sustainability, insulation and health issues) of the intended construction plan during plan approval. During construction a certified independent quality controller has to take care of the inspections. The applicant/ owner and the builder stay responsible for an adequate quality control process. No specific demands are made on the builder with respect to registration or practical experience. The building regulations expect that a builder complies with the regulations. Liability-issues of the various building professionals involved in a project are usually arranged in standard contracts. After completion an end meeting is held that establishes if all the agreements and commitments have been met that were stipulated in the approved inspection plan. If the municipal building committee is satisfied a written notice is issued to the applicant/owner. This written notice is comparable with a completion certificate.

## **4. Discussion**

### **4.1 Focus on the as built situation**

The main goal of a quality control system is to assure that buildings – after they have been constructed - meet the regulatory quality demands. Traditionally the countries studied, focussed their attention on the beginning of the process. Applicants had to submit a plan. During plan approval the drawings and calculations were controlled by local authorities and after the issuing of building approval, construction could start. During construction and at completion the progress and end result were inspected, but emphasis laid on the building approval phase. The countries that are included in this project all have developed systems where the checks and balances have been more evenly distributed throughout the building process. During the process qualified architects and engineers (e.g. Germany and France), qualified builders (e.g. Norway, France, Ireland) and qualified controllers (all countries) have to make sure that constructions meet the demands. After completion controllers, and sometimes builders too, have to report their experiences and the results of the inspections before the local authority issues a completion certificate. With these kinds of procedures in place the chances are fair that buildings meet the intended minimum quality. At the same time all countries have been trying (and still are trying) to streamline and simplify their quality control procedures for construction works. Without exception, the countries studies, decided that deregulation and privatisation was the way forward. This has led to a greater emphasis on the responsibility of building owners and the transfer of actual quality control from municipalities to private parties.

### **4.2 Emphasis on energy regulations**

As we have sketched above the emphasis of quality control has moved from the design phase to the as built situation. Strict regulatory demands are made on the requirements that should be tested and sometimes the way it should be controlled. As we have seen in the country descriptions these demands always focus on the control and inspection of the structural and fire safety requirements.

What is more, these statutory demands on control and inspection always apply to complex constructions. In most countries dwellings are outside the centre of the quality control attention. An example of this is France, where due to the insurance and guarantee system, the structural and fire safety of complex constructions is inspected thoroughly and adequately. Dwellings are hardly controlled by professionals, because the insurance risks are lower. More in a broader sense one can argue if a regulatory system that is heavily funded on insurance regulations is helpful in the face of climate change. The height of the energy use and the sustainable quality of construction does not affect insurance heights and is no driving force to realise a better environmental quality.

The high potential and expected energy savings in buildings increases the need for accurate quality control. As we just have sketched this theme still does not get the attention it deserves in the regulatory developments. However the regulatory infrastructure is already available and more attention for energy and sustainable requirements can be easily incorporated in the current regulatory framework. The first step would be to give energy requirements the same status as currently is being done with structural or fire safety requirements. Private quality controllers should be made explicitly responsible to check these requirements. Only in Norway quality controllers are statutory obliged to control the energy efficiency of complex constructions. Also steps could be made on another policy level. Again in Norway (but for instance also in Ireland) statutory demands are made on municipalities to prioritize supervision on the control of certain requirements. In the period 2013-2014 the national Norwegian ministry ordered municipalities to check if all construction projects met the minimum energy performance demands.

### **4.3 Demands on building professionals**

Other interesting developments are the growing demands on the quality and workmanship of builders and installers. All countries have incorporated various forms of guarantees in their systems to make sure that builders and contractors deliver what they are supposed to do. In England individual installers can certify their own work when they are recognised as competent persons. In France builders have to be registered before they can be qualified for insurance and thus can operate in practice. Ireland is working on a register of builders. In Norway persons and parties who want to perform construction work and building control tasks can be approved and in all cases have to declare that they are fit for the task. In Sweden the builder must appoint a certified site manager who is responsible for the quality control. On top of this, all countries have strict rules for building defects insurances. With these developments a step is made to a further professionalization of builders. However for a successful transition to energy neutral constructions more stern demands must be set on the knowledge and skills of the building professionals. They will have to use new techniques and improve the quality and accuracy of the work. Maybe the English and Welsh Competent Person Scheme could be an example how to deal with the growing need for accurate quality control. This Competent Persons Scheme specifically focuses on construction elements that matter regarding the energy performance of buildings (e.g. windows, glazing and installations). Further study will be needed to determine the accuracy and effectiveness of this scheme.

#### **4.4 Statutory post occupancy monitoring is missing**

Regulatory attention for post occupancy monitoring is completely absent in the countries studied. Some countries have had in the recent past some regulations and guidelines relating to the user phase of constructions. The Home information Pack in England and the Building File in the Netherlands have been mentioned in this paper. Due to political considerations and the fact that parties involved did not support the instrument, the initiatives were stopped. Generally the instruments were considered to be too much of a burden and too expensive. Currently in most countries the quality control procedure ends with the delivery of a completion file. Norway makes even regulatory demands with respect to a user and maintenance manual. Besides that building owners all over Europe have to provide an Energy Performance Certificate when they rent out or sell their buildings because of European regulations. While it may be not foreseeable that post occupancy monitoring will be incorporated in the building regulatory systems of countries, the current practice seems to provide at least a basis for post occupancy monitoring. Besides that the growing big datasets with the actual energy use in buildings provide a wealth of information about the effects of the energy regulations on the actual use of occupants.

### **5. Conclusions**

This paper pictures the state of the art of quality control systems for constructions in seven European countries. What can be noticed in the countries is that the balance slowly shifts from public control and enforcement towards a more dominant role of private parties and building professionals. This development goes hand in hand with the materialisation of more robust and reliable certification and accreditation schemes to guarantee the quality and qualifications of building professionals. With respect to the scope of quality control we see a strong focus on control of the design to monitoring of the building process and testing of the quality of the final building. Post occupancy monitoring is nowhere an established part of the building regulatory system. With respect to the contents it can be noticed that statutory demands on control (when present) usually are focussed on structural and fire safety issues. Of course attention is paid to the check of the energy performance requirements, but the priority in general does not seem to be high. All along the line more simple constructions (e.g. dwellings) are controlled to a far lesser extent. The leading question in this paper was if current quality control frameworks are adequately organized in the light of the regulatory needs related with the expected climate change. In organizational terms the framework looks adequate enough to make the regulations more climate proof. What is needed is the political will and determination to give the energy and sustainable requirements the same status as for instance the demands on structural or fire safety. The last decades the themes energy saving and climate change have been dominating the political agenda. It seems merely a question of time before the regulatory framework will be adapted. In the end however it is also about the question how the systems function in practice. In our future research we intend to lay emphasis on these practical experiences. Only then a more definite and more balanced judgement can be made about the climate ‘proof-ness’ of quality control systems for construction in the various countries.



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# Transaction Costs (TCs) in Building Regulations and Control for Green Buildings: Case Study of Hong Kong

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## Abstract

About 40% of global energy consumption and nearly one-third of global CO<sub>2</sub> emissions are on account of buildings. In Hong Kong, buildings consume up to 90% of electricity during construction and operation, where all the design and construction of private developments is subject to control under the Buildings Ordinance. The way building regulations are applied and the arrangement of supporting systems can affect the effectiveness of building energy consumptions and the corresponding costs induced. Among all the incentives and regulatory instruments, Gross Floor Area (GFA) concession becomes a popular scheme to promote green building (GB), which grant bonus GFA to the developers who comply with the Sustainable Building Design Guidelines (SBDGs) and achieving at least the minimum level of BEAM Plus certification. Transaction costs (TCs) have been debated over the past decades that affect the effectiveness of the policy implementation. This study applies the lens of transaction costs theory to explore the TCs inventories of implementing GFA concession practice in Hong Kong. This paper aims to analyze how the GFA Concession Scheme induces TCs among various stakeholders in practice, and how in turn it affects the effectiveness of building control for GB. Interviews are conducted to identify the TCs determinants regarding the GFA Concession Scheme. Examples are provided from the real practice to illustrate the nature of TCs. Policy implications to reduce TCs are proposed accordingly.

**Keywords:** Transaction costs (TCs), building regulations and control, Hong Kong, Gross Floor Area (GFA) concession scheme, green building (GB)

# 1. Introduction

Building energy consumption accounts for over 40% of global energy use, contributing to one-third of global greenhouse gas emissions (UNEP, 2009). In Hong Kong, buildings consume almost half of all energy and about 90% of electricity (Environmental Bureau, 2008). Apart from energy consumption, building sector influences environment in ways, such as solid waste generation, resource depletion, and environmental damage. Therefore, green building (GB) as a solution of environmental issues gains its popularity and governments' support. Various building standards and design guidelines have been released to regulate the design and construction of GB, such as Building Environmental Assessment Method (BEAM) Plus, and Leadership in Energy and Environmental Design (LEED).

The Gross Floor Area (GFA) Concession Scheme earns its popularity amongst all the incentive and regulatory instruments. The GFA Concession Scheme is developed from the notion of "make developers pay" (Tang and Tang, 1999). Government grants the developers extra GFA bonus in exchange for their contributions to the public amenities so that government can save the public investments (Tang and Tang, 1999). In Hong Kong, it is designed to facilitate the adoption of BEAM Plus and Sustainable Building Design Guidelines (SBDGs). As Hong Kong has restricted land provision each year, extra GFA is very much attractive to developers (Qian, 2010; Fan et al, 2015). After implementing the first GFA Concession Scheme in 2011, the registered GB increased around 30% within one year (Liu and Lau, 2013). In the following years, the registered GB kept increasing, but the percentage of GB is still very small. From 2011 to 2013, only around 30% of total real estate projects participated in the GFA Concession Scheme (Building Department, 2014). It is claimed that transaction costs (TCs) affect the effectiveness of the policy implementation (McCann et al, 2005, Qian, 2012), and hinder developers entering energy efficiency market (Qian, 2012; Qian et al, 2013; Qian et al, 2015a; Qian 2015b,). Therefore, analyzing the TCs amongst the stakeholders induced by the GFA Concession Scheme are essential to understand the low participation rate and ultimately reduce TCs.

This paper aims to analyze how the GFA Concession Scheme induces TCs and therefore affects various stakeholders in practice, and the effectiveness of building control for GB. The section 2 presents the applications of TC theory to the environmental programs that form a foundation for the analysis. The details of GFA Concession Scheme are described in the section 3. The section 4 explains how the three determinants influence the TCs of implementing GFA Concession Scheme. Discussion and conclusion were presented in the section 5.

## 2. Transaction costs (TCs) in the context of environmental issues

Transaction cost (TCs) has been defined by a lot of researchers (Coase, 1937; Arrow, 1969; Williamson, 1985;). In the area of environmental policy, TCs is defined as the cost to create and use a policy (Coggan et al, 2013; Garrick et al, 2013). When it comes to implementing an environmental regulation from the private sectors' perspective, TCs refers to the cost to comply with the regulation (Wong et al, 2011). When analyzing the technology change in building sector, TCs is understood as the cost of technology

arrangement and implementation occurring ex-ante and the cost of monitoring and enforcement occurring ex-post (Qian 2012, Qian et al, 2013, Kiss, 2016). In this paper, TCs is defined as the extra costs to fulfil the requirement of building regulation and control.

The existing literature has studied TC typologies, which are slightly different, associated with implementing the environmental policy and energy efficiency project. For energy efficiency project, TCs include information searching cost, negotiation cost, monitoring and verification cost, trading cost, and decision making cost (Qian, 2012, Mundaca et al, 2013). In the respect of implementing environmental policy, TCs consist of searching cost, negotiation cost, approval cost, validation cost, monitoring costs, verification cost, certification cost, enforcement cost, transfer cost, and contracting cost (Dudek and Wiener, 1996; Ofei-Mensah and Bennett, 2004; McCann et al, 2005; Qian, 2012; Coggan et al, 2013; Qian et al, 2016). Some of these costs are overlapping and it is difficult to divide them clearly. Even if a lot of literature has studied TC types, only a few of them have identified stakeholders who bear the TCs accordingly (see e.g. McCann et al, 2005; Coggan et al, 2013;).

## 2.1 Determinates of Transaction Costs

### 2.1.1 Asset specificity

Williamson (1985) stated that there are three dimensions, namely asset specificity, frequency and uncertainty, influence TCs. To be more specific, there are four types of asset specificity, including site specificity, human asset specificity, physical asset specificity and dedicated assets. Table 1 illustrates the definition of four kinds of asset.

*Table 1: Definition and measurement of three dimensions of TCs (Source: adapted from Williamson, 1985)*

<i>TC determinants</i>		<i>Definition</i>
<i>Asset specificity</i>	<i>Site specificity</i>	<i>Site specificity will arise when specific investments have to be located in a particular site.</i>
	<i>Human asset specificity</i>	<i>The specialized skills, knowledge and learning-by-doing cannot be transferred to alternative transactions</i>
	<i>Physical asset specificity</i>	<i>The specialized instruments and equipment used in a particular transaction</i>
	<i>Dedicated asset</i>	<i>A discrete investment in generalized production capacity to selling number of products to particular buyers, such as expanding the existing plant for a specific customer</i>

Specifically, site specificity, physical asset specificity and human asset specificity exist for the environmental goods for the reasons that the transaction value of an environmental good largely depends on the site (site specificity) and inputs (physical asset specificity), and the transaction needs investment in specific knowledge (human asset specificity) (Coggan et al, 2010).

### **2.1.2 Uncertainty**

Three types of uncertainties surrounding the transactions are extracted from Williamson (1985) and explained in the context of agri-environmental scheme by Mettepenningen and Van Huylenbroeck (2009). The uncertainty of future state of nature is primary, which means that the environmental outcome of certain transactions could have high uncertainty because of the uncertain physical and natural environment. The secondary uncertainty arises due to lack of communications between contracting partners. This type of uncertainty is understood as the uncertainties resulted from implementing poorly specified contract. The third type of uncertainty refers to behavioral uncertainty attributable to opportunism. In the context of environmental scheme, it concerns the trust between contracting partners.

### **2.1.3 Frequency**

Frequency refers to the frequency of transactions, which influences TCs by recovering the costs of specialized governance structures (Williamson, 1985). TCs could be reduced by repeated transactions because of fewer efforts on information collection and learning (Mettepenningen and Van Huylenbroeck, 2009). However, it is important to notice that only if the past experience is transferable to new experience, TCs can be reduced (Coggan et al, 2015). Therefore, TCs are essentially reduced by the transferable past experience developed in the transactions, such as transferable knowledge, skills, information, etc. In this sense, an incentive scheme should contain more transferable knowledge or skills to reduce TCs.

## **3. GFA Concession Scheme to control building design and construction**

Since 2011, Hong Kong has implemented Gross Floor Area (GFA) Concession Scheme to promote GB development and address climate change, which grants GB developers additional GFA (up to 10%) to reward their contributions on the built environment. This scheme is voluntary basis, but regulates the GB design and construction by the twelve green and innovative features, Sustainable Building Design Guidelines (SBDGs) and Building Environmental Assessment Method (BEAM) Plus that are tailored for the Hong Kong built environment. Developers who would like to acquire extra GFA have to comply with SBDGs and BEAM Plus and the certain green or innovative building. In this way, environmental protection could be guaranteed, especially building energy efficiency addressing climate change.

The SBDGs have three basic elements for GB design, namely building separation, building setback and site coverage of greenery, which contributes to better air ventilation, enhancing the environmental quality of living space, and providing more greenery and mitigating the heat island effect. Specifically, for different sizes of sites, building height, building length, and assessment zone, there are different design requirements for each of three elements. For example, in terms of building separation, in the site area less than 20,000 m<sup>2</sup> and with building length no less than 60m and building height no more than 60m, the permeability of buildings should not be less than 20%. The complicated requirements bring a lot of difficulties to the architects to make the design scheme, especially in the situation that no specific training is provided. According to the Environmental Report (Building Department, 2014), from 2011 to 2013, around 25% of total projects applying for GFA concession get disapproval due to failing to fulfil the SBDGs.

BEAM Plus has four ratings, namely Platinum, Gold, Silver, and Bronze. It is designed to control the process of building construction and operation in the aspects of building site, material, energy use, water use, and indoor environmental quality, which respectively have the total credits of 22, 22, 42, and 32 to achieve. Each credit has specific requirements illustrated in the BEAM Plus, but without implementation measures. However, Hong Kong Green Building Council (HKGBC) provides trainings particularly to help professionals integrate GB standards and practices, and advise project team on how to achieve the credits. Professionals who take the training of BEAM Plus and pass the exam can get the certification of BEAM Pro. Nevertheless, it is not mandatory to employ BEAM Pro to do GB project, but BEAM Pro's involvement can get the project one credit bonus.

There are five green features and seven amenity features that can be granted GFA concession, subject to 10% overall cap. The architects would integrate several of these features into the design scheme depending on the site context and building layout (Development Bureau, 2011). Apart from the twelve features, other features beneficial to community with practical need or environmental friendly (e.g. communal sky gardens, covered walkway with provision of greenery) and other items (e.g. car parks, sunshades and reflectors) could be granted GFA concession as well with no overall cap of GFA concession. Therefore, the architects should be familiar with the SBDGs, BEAM Plus and the above building features in order to implement the GFA concession well.

## **4. Determinates of TCs in the GFA Concession Scheme**

### **4.1 Asset Specificity**

Applying the TCs theory to the GFA Concession Scheme, asset specificity means the specific investments to do the GFA concession projects. To be more specific, four types of asset specificity exist in the GFA Concession Scheme. Site specificity refers to the GB design for the specific site. Each site has its particular size, shape and surroundings that restrict building design and construction by the GFA Concession Scheme. Therefore, the traditional design pattern may be changed to adapt to the new rules, which causes research cost borne by architects. Human (knowledge) asset specificity is understood as the specific knowledge and information required by the GFA Concession Scheme. For example, participants of the GFA Concession Scheme have to learn the SBDGs, BEAM Plus and collect relevant information that causes learning cost and information searching cost. Physical asset specificity refers to the investment in the specific contract between stakeholders. Stakeholders need to negotiate and clarify the responsibility of each participant, and do some research to develop the non-standard contract particularly suitable for the GFA concession project, which generates TCs in the process like negotiation cost and research cost.

### **4.2 Uncertainty**

Adapting three types of uncertainty to the GFA Concession Scheme, they refer to the technology uncertainty arising from uncertain performance of green equipment, the institutional uncertainty due to ambiguous contracting or government documents and behavioural uncertainty because of opportunism and bounded rationality. Technological uncertainty exists in the process of implementing BEAM Plus. To achieve the credits of energy and water saving, the applicants have to provide evidence as to the energy

efficiency rating, which generate verification costs. Institutional uncertainty arises due to the poorly specified official documents. For example, BEAM Plus does not specify how to achieve the credits in the handbook, which leads to extra communications between practitioners. Behavioural uncertainty also brings more communications due to lack of trust and common understanding in the new partnership, such as partnership of GB consultant and architects, GB consultants and contractors, and contractors and new suppliers.

### **4.3 Frequency**

Frequency in the GFA Concession Scheme means how frequently the experience, such as knowledge, information, and partnership, gained in the previous GFA concession project could be used in the later projects. In other words, it is the transferability of experience that influences TCs. Therefore, transferability is employed to measure to which extent the TCs in the GFA Concession Scheme could be reduced. For example, the communication costs could be saved if architects and contractors keep working with the same group of GB consultants as they have developed common language and working pattern.

## **5. TCs analytical framework**

Starting with the TCs determinants in the GFA Concession Scheme, through literature review a preliminary list of TCs are identified, and mapped on the stakeholders who bear them (Table 2). 10 interviewees (Appendix 1), including architects, developers, contractors and BEAM consultants have been interviewed to verify the list in the Table. According to Table 2, information searching cost, research/learning cost, coordination/negotiation cost, approval cost, monitoring cost, and verification cost exist in the process of the GFA Concession Scheme implementation due to the specific knowledge, specific information, specific contract, design for specific site, behavioural uncertainty, institutional uncertainty, and technological uncertainty embedded in the GFA Concession Scheme design. All the stakeholders have borne the extra TCs. Specifically, professionals bear the TCs most frequently in the transactions, followed by contractors. Developers ranked 3rd, followed by suppliers. However, this frequency does not mean that professionals bear the highest TCs because each type of TCs may cost different in time and efforts. In Table 2, we will derive a set of specific transactions under each of the sub-determinants to conduct interviews with experts later to extract the more detailed TCs incurred.

As discussed before, frequency influences TCs by reducing the time and efforts spent on the information collection and learning in the repeated transactions, but only the transferable experience gained in previous transactions, can reduce TCs. Therefore, transferability should be employed to measure the potential of the GFA Concession Scheme to reduce TCs. It indicates how efficient the GFA Concession Scheme able to be implemented when the market progresses mature.



Table 2: Analytical framework of transaction costs in the GFA Concession Scheme (Source: Interview)

TCs determinants	Sub-determinants regarding the GFA Concession Scheme	TCs caused by GFA Concession Scheme						Stakeholders:
		Information searching cost	Research/earning cost	Coordination/Negotiation cost	Approval cost	Monitoring cost	Verification cost	
Asset Specificity	Specific knowledge		ü					P, C, S
	Specific information	ü						P, D, C
	Specific contract		ü	ü		ü		P, D, C, S
	Design for specific site		ü	ü			ü	P, D
Uncertainty	Behavioural uncertainty	ü		ü				P, C, S, D
	Technology						ü	C
	Institutional uncertainty			ü		ü		P, C

Note: P: Professionals, C: Contractors, S: Suppliers, D: Developers

## 6. Discussions and Conclusions

### 6.1 Other private sectors bearing extra TCs with no evident benefits except for developers

All the key stakeholders in private sectors have borne TCs due to the implementation of the GFA Concession Scheme (Table 2), but only developers can benefit directly from this scheme with bonus GFA. It in turn influences the effectiveness of the GFA Concession Scheme negatively. It seems that the developers have to use GFA concession to offset the extra TCs. If they pay other participants more for their extra efforts, developers will benefit less from the GFA Concession Scheme. In this situation, developers may not have interests in GB development because of its high opportunity cost. If nobody can obtain extra fee from developers in a competitive market, all the other stakeholders have to absorb the TCs by themselves. This may explain the slow growth of the GFA concession projects. If 10% GFA concession is the only benefit, TCs must be reduced to make the GFA Concession Scheme implemented more efficiently. It is obvious that at the time of designing the GFA Concession Scheme, TCs were ignored. It has affected the implementation efficiency of the GFA Concession Scheme and should be taken into considerations when design the benefits allocation of the GFA Concession Scheme.

## **6.2 TCs changed with the design of the policy instrument and highly specific to the policy**

It is recognized that three dimensions, asset specificity, frequency and uncertainty, of the GFA Concession Scheme would induce TCs. This paper identified the sub-determinants regarding the GFA Concession Scheme. It illustrates that at the time of designing the building regulations and control, the transaction determinants have been generated. For example, the BEAM Plus is designed ambiguously, which leads to a lot of transaction uncertainties and induces TCs. Therefore, if the BEAM Plus is changed to be more precise, and participants only need to follow the certain standards, the TCs resulted from transaction uncertainties could be reduced. Mover, every policy instrument has its own sub-determinants under the three main transaction dimensions, which induce different types and the amount of TCs. Therefore, TCs are highly specific to the policy, as supported by Mundaca et al (2013). However, there are some common relationships between the regulation design and TCs involved: 1) the more criteria the regulations have, the more TCs induced; For example, before 2011, developers could also apply for the GFA concession as long as they provide the twelve building features according to the Joint Practice Note (JPN) 1 and JPN 2. While after 2011, they have to comply with the SBDGs and BEAM Plus that are prerequisite to be granted GFA concession. This induced a lot of TCs in the process (see Table 2). 2) The more stakeholders involved, the more TCs induced. For instance, to fulfil the BEAM Plus, GB consultants have to be involved that induces more coordination and negotiation costs. 3) The more precise and standard the regulations are, the less TCs borne by private sectors. As mentioned, BEAM Plus is ambiguous that participants have to spend more time reducing uncertainties.

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## Appendix 1

<i>Profession</i>	<i>Qualification and Position</i>
<i>Architect</i>	<i>Authorized person; more than 20 years working experience; Director of Architectural firm</i>
<i>Architect</i>	<i>Registered architects; Chairman of architectural firm</i>
<i>Architect</i>	<i>Authorized person; Hong Kong Institute of Architects Fellow Member</i>
<i>Architect</i>	<i>Senior architect; Working in leading architecture firm for 5 years in Hong Kong; All the projects the architect has joined are green buildings.</i>
<i>Architect</i>	<i>Manager, working in leading architecture firm that all the projects it did are green buildings.</i>
<i>Developer</i>	<i>CEO in one of leading real estate development firms in Hong Kong</i>
<i>Surveyor</i>	<i>Green building professional, environmental officer working in leading construction firm. Familiar with LEED and BEAM Plus.</i>
<i>Surveyor</i>	<i>Authorized person; Project director of consultancy firm</i>
<i>Surveyor</i>	<i>Director of consultancy firm</i>
<i>Professor</i>	<i>Over 10 years working experience in project management and building control</i>

# Regulating for climate change related overheating risk in dwellings

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## Abstract

There is broad scientific consensus supporting the link between CO<sub>2</sub> emissions and climate change. In cool and temperate climates such change is predicted to result in (among other impacts) warming ambient temperatures. As in recent years buildings in such locations have been increasingly optimised for heat retention (through regulations and standards), a warming climate has the potential to have a significant impact on the built environment and there is already evidence of overheating in new and recently constructed buildings.

Regulations in the built environment are largely designed to address issues of health and safety. In recent times however, such regulations have increasingly sought to incorporate issues related to energy efficiency while being used to implement national carbon reduction targets at the building scale. Arguably, building regulations remain focused on the ‘point of handover’ or near term performance, which given the uncertainty associated with predictions (such as climate change, occupant behaviour or technological change) is understandable. Such an approach however, in a situation where the current existing stock is seen as a major barrier to carbon reduction, risks buildings delivered today becoming prematurely obsolete due to the impacts of climate change.

Current overheating risk assessments in building regulations may not be appropriate as they are largely based on historic climate data. There remains a role however for regulations and standards that take account of the potential impacts of climate change. Building upon earlier research by the authors that demonstrates the potential magnitude of the overheating risk for UK dwellings, this paper suggests a risk based regulatory approach to overheating assessment based on climate change predictions while incorporating a requirement for adaptation planning. The approach put forward is based on semi-detached dwellings, built to new and emerging standards and regulations and aims to ensure that short term efficiency is not compromised for long term performance and comfort, thus minimising the potential for premature obsolescence related to overheating.

**Keywords:** Adaptation planning, Building regulations, Climate change, Dwellings, Overheating risk

# 1. Introduction

The built environment is responsible for a large proportion of global energy use and corresponding CO<sub>2</sub> emissions, with the residential sector using 18% of energy in 2011 (U.S. Energy Information Administration, 2015). In that context and with the drive to reduce such CO<sub>2</sub> emissions and thus mitigate against climate change, there has in recent years been a drive to make our dwellings more energy efficient. Building regulations have set increasingly ambitious energy reduction targets while other standards and assessment methods have emerged which go beyond the minimums of the building regulations (such as the Passivhaus standard). In cool and temperate climates increasing efficiency largely means optimising buildings for heat retention, with increasing levels of insulation and air tightness significantly reducing energy consumption.

Although the drive to improve efficiency, reduce emissions and minimise the potential for climate change is well founded, as noted by the IPCC (2007) a certain amount of warming is now inevitable. In cool and temperate climates there is evidence that this change may result in overheating (for example Jenkins et al., 2014a and Dodoo et al., 2014). Adaptations to alleviate overheating (Porritt et al., 2012) may help reduce the risk, however such adaptations may result in costs that some sectors of society cannot afford (Hills, 2012). In this context there is a need for building regulations to consider the impacts of predicted climate change. Furthermore, as ambient temperatures warm it is likely that occupant behaviour may become an increasingly important factor where clothing, work and lifestyle patterns may have to adjust.

This paper, which builds upon an earlier publication by the authors that sought to understand the magnitude of the potential for climate change related overheating (Mulville and Stravoravdis, 2016), presents a risk based approach for dealing with such overheating. Such an approach could form part of a regulatory framework that considers the potential impacts of climate change. The proposed approach aims to ensure that short term efficiency does not result in an unacceptably high overheating risk in the long term, thus attempting to take account of the lifetime performance of the building.

# 2. Literature Review

Roaf et al. (2015) suggest that the long life of buildings presents a challenge in developing '*fit for purpose*' regulations and standards in the context of climate change.

Most studies that seek to explore overheating related to climate change in dwellings do so using predictive building simulation models, considering how building specification, building type and/or location can impact on the magnitude of the overheating (for example see Peacock et al., 2010 and McLeod et al., 2013). Some studies consider the potential benefit of technical building adaptations to reduce overheating (such as Porritt et al., 2012) while others also consider the role of occupant adaptations linked to behaviour (such as Mavrogianni et al., 2014). In this context the review that follows focuses on the evidence for current and predicted overheating, how this may be avoided, how the current overheating assessment methods may contribute to this and what alternative approaches may be of benefit.

## 2.1 Evidence of overheating

There is evidence that new, recently constructed and well insulated dwellings may already be experiencing overheating, especially during warm summers (Dengel and Swainson, 2012). In support of this McLeod et al. (2012) suggest that highly insulated buildings in the UK, Ireland and Northern Europe may be at risk of overheating, arguably as they have been optimised for heat retention.

Going forward, the frequencies of such problems are predicted to increase. Jenkins et al. (2014a) suggest that by the 2030s, 76% of flats and 29% of detached dwellings in the UK could be at risk of overheating. Furthermore, Dodoo et al. (2014) in a study considering the potential impact of climate change on overheating risk for ‘conventional’ and ‘Passive House’ dwellings in Sweden, predicted significant increases in cooling demand by 2050 (reductions in heating load were also predicted). The research predicted a proportionately greater increase in cooling demand for the highly insulated Passive House building. In support of this Orme and Palmer (cited in Dengel and Swainson, 2012) note that increasing levels of insulation can result in increasing overheating risk. De Wilde and Tian (2012) suggest that buildings may be more resilient to climate change than expected due to the relatively short life expectancy of systems, presence of additional capacity in those systems and opportunities to install new systems. However, Peacock et al. (2010) note that an increase in installed air conditioning could result in occupant behaviour that accentuates energy consuming behaviour. A challenge in how to deal with overheating risk remains.

It has been suggested that raised temperatures in bedrooms overnight is a particular risk (Naughton et al., 2002 as cited in Peacock et al., 2010), where temperatures above 24°C have been linked to impaired sleep and health implications (Dengel and Swainson, 2012). In this context Peacock et al. (2010) suggest that where high bedroom temperatures overnight are problematic, the use of a ‘cooling nights’ metric may be of benefit.

## 2.2 Overheating assessment methods

Given the evidence of overheating in new and recently constructed buildings it can be argued that the current approach to overheating risk assessment may not be fit for purpose. In regulations, assessments related to overheating risk are often made using relatively simplistic steady state tools (such as SAP UK (Department of Energy and Climate Change [DECC], 2014). This may be due to the complexity and resource needed to conduct, potentially more accurate, dynamic simulation based assessments (Jenkins et al. 2013). It has been argued that the current approach cannot account for the potential impacts of a warming climate as much of the climate data used is historic (de Wilde and Coley, 2012). Furthermore, it has been suggested that the current approach to overheating risk assessment may also allow for unrealistic user adaptations, such as window opening (Mulville and Stravrovadis, 2016).

Peacock et al. (2010) note that there remains a role for policy in addressing elevated temperatures in dwellings. Jenkins et al. (2013) suggest that using an alternative approach based on overheating frequency curves derived from regression analysis of a range of climate predictions and analysed



using dynamic simulation for specific buildings, may improve predictions and allow for the consideration of risk. Expanding on the proposed overheating risk curves (Jenkins et al., 2014b), it is suggested that potential user adaptations, such as opening windows and technical intervention (such as shading and the reduction of internal gains) could be included in the assessment. The approach does still require significant knowledge of the building operation and building characteristics, however it greatly reduces the amount of simulation required and may help designers to contextualise the problem (Jenkins et al., 2013). Jenkins et al. (2013) argues that any methodology used to assess overheating should be industry focused and able to include a range of building types, glazing ratios, building characteristics and locations.

## **2.3 Reducing overheating risk**

McLeod et al. (2013) found that in highly insulated dwellings, external shading followed by adjustments to south-facing glazing ratios had the greatest potential to reduce overheating risk. Supporting this, Porritt et al. (2012) suggest that the control of solar gains (shading, shutters, glazing specification), solar reflective coatings and insulation (the study was based on dwellings with low levels of existing insulation) could also help reduce overheating risk. Furthermore, increased ventilation (Porritt et al., 2012) and higher levels of thermal mass (Gupta and Gregg, 2012) have also been shown to be of benefit although in both cases there are potential limitations. Peacock et al. (2010) note that although during the day time thermal mass would appear to have significant advantages, overnight the measured benefits may reduce as stored heat from day-time heat gains is radiated back into the spaces. This is supported by McLeod et al. (2013) who found that although overall temperatures in high thermal mass buildings were lower than in others, bedrooms in light weight buildings cooled more rapidly (in the 2080s). Where raised temperatures in bedrooms have been shown to be problematic (Dengel and Swainson, 2012) this potentially presents a risk and the perceived benefits of thermal mass in dwellings may be questionable.

Window opening may help to reduce overheating risk. However, Mavrogianni et al. (2015) suggest that window opening in urban centres may have negative health impacts, with Tong et al. (2016) highlighting the link between raised indoor air pollution and proximity to roads. This is supported by Peacock et al. (2010) who note that window opening is likely to be limited by noise, pollution and security in urban areas. In addition to the discussion about window opening behaviour there is evidence that in the future the benefits of such window opening may reduce. Peacock et al. (2010) found that although increased ventilation still had benefits this was not enough to overcome the overheating issues predicted for London in the 2030s.

Gupta and Gregg (2012) note that adaptations to reduce overheating risk could result in some increase in heating demand and suggest that phased adaptations over the lifetime of the building may be of benefit. In this context Jones et al. (2015) set out an approach to adaptation planning related to the predicted impacts of climate change. Although based on a non-domestic building, the approach suggested that where future problems were identified an adaptation plan could be developed to enable the building to be altered on a cost-effective basis when required. Where interventions in the future may prove prohibitively expensive, but predicted risk is high, enabling works to allow the future adaptation could be incorporated into the initial construction phase.

### **3. Methodology**

As detailed in the earlier paper associated with this research (Mulville and Stravoravdis, 2016), and summarised here, this study used dynamic simulation modelling for a ‘typical’ (UK) semi-detached dwelling coupled with climate change predictions to understand the level of overheating risk. To understand how the heat retention parameters of the fabric impact upon the potential overheating risk, five standards were chosen and associated construction specifications developed to reflect these construction standards (UK Part L 2006 and 2010, ‘Good Fabric’, ‘Advanced Fabric’ and the Passivhaus standard). The construction system used was also varied to reflect a range of potential levels of thermal mass (low, medium and high options). For the purposes of this paper the analysis and results presented are based on a North-South orientation only.

#### **3.1 Simulation approach**

The ‘typical’ building was modelled using Ecotect® software (Marsh, 1996) which was then exported to Heat Transfer in Buildings 2 (HTB2) software (Lewis & Alexander, 1990) for the purpose of dynamic simulation and analysis. The models were then ‘run’ for the summer months using a range of current and probabilistic future reference years (climate files) based around the prediction of the UKCP09 weather generator and developed as part of the PROMETHEUS project at the University of Exeter (as detailed by Eames et al., 2011). For the purposes of this work the 50<sup>th</sup> percentile medium scenario predictions were chosen. The results presented in this paper are based on Design Summer Years (DSYs) representing near extreme scenarios. In addition a range of possible window opening positions, where included in the modelling.

#### **3.2 Overheating assessment approach**

The adaptive comfort approach to predicting overheating as detailed by Nicol and Spires (2013) was used to determine when overheating may have occurred and to gauge the magnitude of the overheating identified. This is represented by three overheating criteria. Criteria one was based on the comfort threshold being exceeded, criteria two considered the severity of the overheating in a given day and criteria three set an absolute maximum allowable temperature. In each case the temperatures were related to a running mean of outdoor temperature and were analysed based on the outputs of the preceding modelling approach. Exceedance of any two of these three criteria, as detailed by Nicol and Spires (2013), was then considered to represent an unacceptable level of overheating. As noted in the preceding research to this paper (Mulville and Stravoravdis, 2016), there remains a debate about the most appropriate metrics to be used. As a result, additional analysis was carried out based on exceedance of specific temperatures.

## 4. Overheating Risk

This research sought to consider the potential impact of a warming climate on dwellings. In this case a ‘typical’ semi-detached dwelling was chosen and analysed using dynamic building simulation and probabilistic climate scenarios for a southern UK climate.

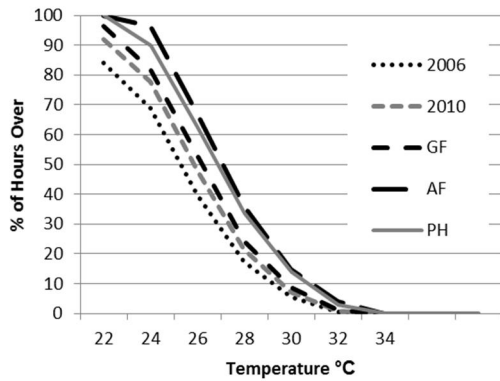


Figure 1: Temp. frequency curve  
– Across standards

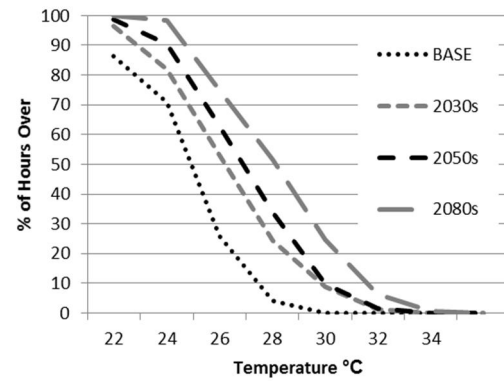


Figure 2: Temp. frequency curve – Overtime

### 4.1 Predicted overheating patterns

Figures 1 and 2 are based on scenarios where windows are able to be opened to the ‘slightly opened’ position (triggered by internal temperatures thresholds and appropriate outdoor temperatures to aid cooling) which represents one air change per hour and a medium thermal mass construction. As can be seen in Figures 1 and 2 there is a general increase in temperatures and therefore overheating risk as fabric heat retention criteria increase (insulation levels, air tightness, glazing specification etc.) and the climate warms. This was also reflected in the wider analysis across all thermal mass and window opening scenarios. The Passive House standard did appear to offer some protection from overheating when compared with the ‘Advanced Fabric’ building, with 6.6% reductions in the 2030s, 6.8% in the 2050s and 7.2% in the 2080s observed in certain scenarios (see Mulville and Stravrovadis, 2016). This is arguably due to the greater emphasis on

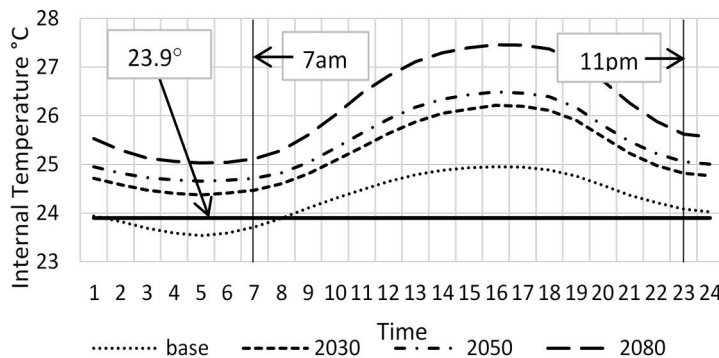


Figure 3: Daily temperature profile (HTM, Good Fabric)

solar protection required by the Passive House standard and possibly a more robust overheating assessment. Thermal mass was also found to offer benefits in reducing levels of overheating with reductions of 15% observed in the 2030s, however the benefit for highly insulated options (Advanced Fabric and Passive House) may reduce between

the 2050s and 2080s. This could be related to a reduction in internal to external temperature differences over time, with for instance a reduction in the mean internal to external temperature difference for the Advanced Fabric building of 3.36°C observed between the base case and the 2080s. This in turn reduces the ability of ventilation air to cool the building fabric. As demonstrated in Figure 3, which is based on slightly open windows, as the temperature warms due to the impacts of climate change, night-time bedroom temperatures frequently exceed the 23.9°C threshold (as noted by Peacock et al, (2010) this is the temperature at which bedroom occupants at night may begin to feel uncomfortable and may seek to change the conditions) during peak summer. This does reduce where windows can be opened further (see Figure 4, based on ‘half open’ windows in the 2030s), but the issue remains. Exploring this in more detail it is found that although thermal mass can, as noted above, reduce overall levels of overheating (measured against the adaptive comfort criteria), temperatures are higher overnight for the high thermal mass solution compared to the low thermal mass solution (see Figure 4). This can be related back to the suggestion by McLeod et al. (2013) that heavy weight buildings may contribute to raised

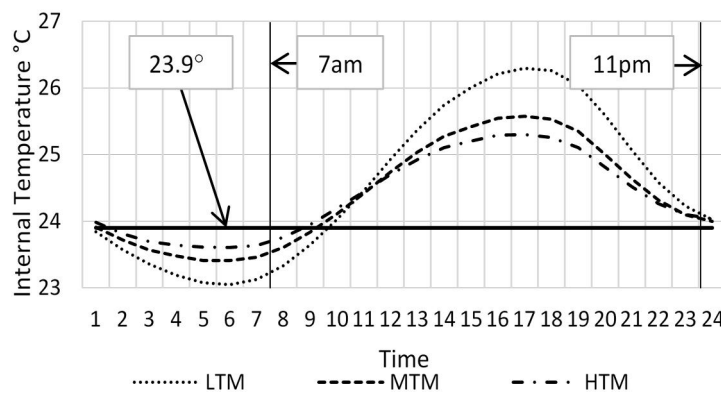


Figure 4: Daily temperature profile (Good Fabric – 2030s)

temperatures in bedrooms overnight due to the re-admittance of stored gains into the space. As demonstrated by comparing Figures 3 and 4 window opening to increase ventilation offers benefits, although as previously noted such benefits may reduce over time and concerns regarding air pollution, noise and security remain.

In the context of the analysis presented here, it can be argued that there is a need for more robust building regulations that take a longer term view in relation to overheating risk assessment. There is also a need to explore overheating metrics in relation to overnight bedroom temperatures.

## 4.2 Building overheating risk categorisation criteria

Based on the preceding discussion (and findings of the previous research to this paper (Mulville and Stravoravdis, 2016)) it can be argued that the main risk criteria related to overheating in dwellings are overall fabric heat retention parameters (insulation levels, air tightness, window specification), thermal storage parameters (mass) and opportunities for occupant adaptation (window opening). There remains questions around both thermal mass and window opening in relation to long term benefits, overnight temperatures and urban environments. In addition, building on the findings from previous studies, building configuration (semi-detached, terraced, flat etc. and orientation (including shading)) and insulation position (which could be included in the ‘heat retention parameters’) are also risk categories. This study did not seek to rank the relevant importance of these risk categories, but instead considered how the potential combinations of these criteria are likely to contribute to overall overheating risk (see Figure 6).

### 4.3 Proposed risk based assessment approach

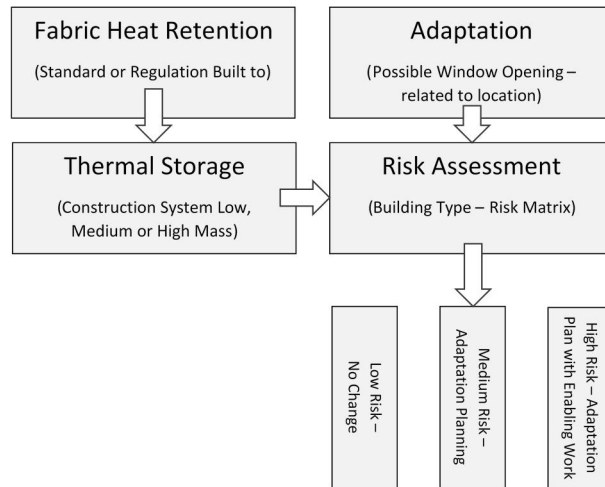


Figure 5: Proposed Approach – Flow Chart

As noted by BJM (2009) cited in de Wilde and Tian (2012) a risk can generally be stated as ‘probability x consequence’. In this case the probability is that overheating risk derived from dynamic building simulation and the consequence is the impacts of that overheating. In any risk assessment the weightings of parameters used should reflect their relative importance. In this case exceedance of the adaptive comfort criteria is used to determine the level of risk. This is based on the relevant running mean of acceptable temperatures. As raised bedroom temperatures at night time have been shown to be problematic and as the benefits of thermal mass in reducing overheating during the day may reverse overnight, a debate remains regarding the most appropriate metrics to use. If raised temperatures in bedrooms overnight (above 23.9°C) was used as the overheating metric in this study the risk matrix presented in Figure 6 would be significantly different. The adaptive comfort criteria as described, coupled with the risk criteria previously noted (fabric heat retention parameters, thermal storage parameters, adaptation options and building configuration) are combined to create the risk matrix displayed in Figure 6. A flow chart of the assessment process is presented in Figure 5, detailing the steps taken to reach the appropriate point on the risk matrix. One of the key input criteria for the proposed approach is the possible window opening position. Permissible window opening positions must be linked to the location of the building and a decision made based on exposure to pollution and noise along with an assessment of potential security concerns. The risk matrix as presented considers the 2030s only, arguably a weighted matrix could also include predictions for the 2050s and 2080s. However, as noted by de Wilde and Tian (2012) longer term predictions become increasingly uncertain due to the range of assumptions association with maintenance, systems and renovations etc. As a result, in this case a shorter term assessment is presented, although longer term predictions may also have merit where the level of uncertainty can be taken into account.

As noted by Gupta and Gregg (2012) interventions made now could result in increased heating demand. In this context regulations dealing with overheating should aim to optimise lifetime building performance while minimising the risk of future overheating. An approach integrated with adaptation planning and backcasting/forecasting (Jones et al., 2015) could help to deliver whole life performance. Therefore, the output of the proposed approach is requirements for adaptation planning, adaptation planning with enabling works or a change in the approach taken based on the level of risk identified. As an example, taking a dwelling in an urban area where

only slightly open windows may be possible. If built to the ‘Good Fabric’ condition with low thermal mass, this dwelling would be at high risk of overheating (see Figure 6) and would require an adaptation plan with enabling works to allow for future adaptations (such as preparations for the installation of shading). As this is likely to add cost, it may be that the designer/ developer would choose to avoid such a scenario. In that case, a change in construction system to a medium thermal mass level has the effect of reducing the risk and removing the requirement for enabling works,

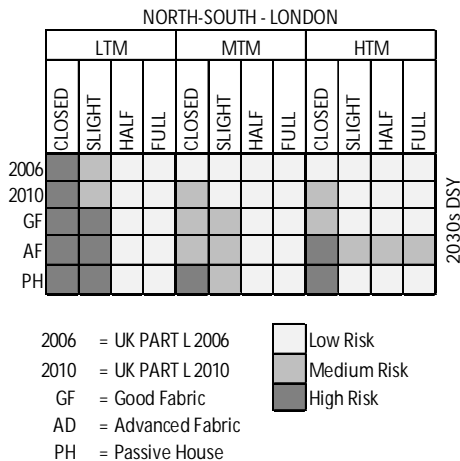


Figure 6: Risk Matrix (adapted from – Mulville and Stravoravdis, 2016)

while a high thermal mass solution would move the building into a low risk scenario. This approach must be considered in the context of the previous comments about the potential impact of thermal mass on overnight temperatures in bedrooms. However, if appropriate overheating metrics could be assigned, the approach outlined could help to ensure that current performance is not compromised to avoid longer term overheating. The approach, as such, incentivises the designer/developer to favour a low risk scenario while accounting for a range of building characteristics (as suggested by Jenkins et al., 2013) and favouring phased adaptations (as suggested by Gupta and Gregg, 2012).

## 5. Discussion & Conclusion

The overall installed capacity of artificial cooling in UK dwellings remains low (Hulme et al., 2011). However, if the potential increase in overheating as predicted is realised the installed capacity could increase significantly (Peacock et al., 2010). Although there is likely to be a corresponding reduction in heating demand (Dodoo et al., 2014) and with technological change the overall increase in carbon emissions may be minimal, increased use of artificial cooling could have a negative impact on the energy use behaviour of occupants (Peacock et al., 2010). Furthermore, if the overheating risk is not addressed a shift from winter to summer time fuel poverty could be observed, with corresponding health, wellbeing and societal impacts. As discussed, the current approach to overheating risk assessment may not be fit for purpose as it does not take account of climate change projections and may assume unrealistic adaptations.

The proposed approach to overheating risk assessment utilises the increased accuracy of dynamic building simulation modelling (when compared to steady state assessments) (Jenkins et al., 2013), while reducing the amount of resource required and presents an approach that could be applied by industry. If risk matrices for a range of building types, in a range of locations could be developed a large proportion of the ‘typical’ new stock could be represented. The requirement for adaptation planning based on the level of risk identified would help to ensure that pathways focused on long term performance can be developed for the dwellings in question. This approach could be tied to the likely major refurbishment points for the building, such as when windows etc. have reached the end of their useful life.

The findings of this research demonstrate that, by using risk based assessments implemented through the building regulations, it may be possible to take account of the potential impacts of climate change (in this case overheating) while considering the inherent uncertainty of such predictions. The implications for building regulations is a shift from a '*point of handover*' approach towards a forecasting role. Such forecasting must be approached with caution and an appreciation of risk and probability to avoid unintended consequences. Arguably, given the potential impacts of overheating on occupants, this refocuses on the traditional health and safety role of the building regulations while accounting for energy performance on a whole of life basis.

As noted, the metric used can have a significant impact on the level of risk identified. This is particularly true in relation to temperatures in bedrooms overnight, where issues related to the relevant benefit and drawbacks of thermal mass may also be important. Further research in relation to developing overheating metrics in dwellings that takes these issues into account would be of benefit. In addition, as the research demonstrated, window opening to increase ventilation can have a significant impact on reducing overheating risk. However, in some scenarios presumed window opening behaviour may be unrealistic or may result in negative health impacts related to pollution. Further research into window opening behaviour in dwellings, particularly in urban areas subject to noise, pollution and security issues would be of benefit.

## 6. Limitations

The approach taken in this study must be considered in relation to a number of limitations. A medium level, 50<sup>th</sup> percentile prediction was used and a wider consideration of potential climate scenarios may add depth to the assessment. In addition the building simulation approach used includes a number of assumptions related to internal gains and occupancy patterns that cannot be easily predicted. Although a range of 'typical' buildings could be addressed if this approach was expanded to include other configurations, the criteria that define 'typical' would need to be carefully developed. A range of dwellings that cannot be easily categorised would remain and these would require more resource intensive building specific assessments.

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# Ten years of performance building code in Spain (2006-2016): facing the challenge of climate change

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## Abstract

Spain has experienced various important changes in the first years of this century regarding the building activity. A new building act, which clearly defined, for the first time, the objectives, the sector stakeholders, competencies, responsibilities and guarantees, was followed by the approval of a performance building code. This new regulatory frame seemed a good tool to fulfil the ambitious energy efficiency goals set in parallel by the EU, but arising problems are threatening today its capacity to face the challenge, at least as a single actor.

The severe economic crisis, affecting specially the building activity, which dropped sharply from 2007, has slowed down the impact of the code. The complexity of the Spanish legal system, with shared competences between the State, the Autonomous Communities and the Cities does not contribute to set clear common criteria, methods and administrative procedures. The strong tradition of inefficient building control is based exclusively on formal document completion, but not on real performance evidence. The existing building stock, under none or very low standards, that will represent in the future a big percentage of the total, is almost out of the scope of the code. To complete the panorama, important social issues as unemployment, energy poorness and changing demographics make very difficult to progress towards facing effectively the threat of climate change.

An important change in building regulations and control is to be produced in the country in a near future, requiring a real structural change. On the one hand, diminishing regulations will help to reduce the administrative burden, allowing flexibility and saving time and money in the first steps of the process. It will simplify also the differences between the various regulatory bodies. On the other, an effective performance control at the end will help to ensure quality and act as a real driver for the different stakeholders.

**Keywords: Building Regulations, Building Control, Climate Change, Building Stock, Building Performance**

# 1. Introduction

Spain experienced a key regulatory change in 1999, when the Building Act (1999) was approved by the Parliament. For the first time, the Country had a document which clearly defined the Building Objectives (Habitability, Safety and Functionality), the stakeholders and their competencies and the guarantees for final users.

The Building Code, approved in 2006, developed the Building Act Objectives in Performance Requirements (2006). It was intended to be a well-organized normative framework to facilitate their fulfilment in harmony with European regulations. It included five Energy Saving Requirements to accomplish the objective of “a rational use of the energy”: limitation of the energy demand, efficiency of building systems, efficiency of lighting systems, minimum solar contribution for hot water production and minimum contribution of PV for electricity production.

The structure of the Code was, in fact, based on the one outlined by the Nordic Building Codes Committee in the 1970s, but it remains incomplete if compared with the more advanced scheme proposed by the IRCC. As Meacham and others (2004, 2005 and 2010) have pointed out, a complete Performance-Based Building Regulatory Framework needs to be informed with accurate data from the building, the users and the tolerable risk levels.

Unless some aspects traditionally addressed by building regulations are relatively easy to quantify, to effectively implement and to follow by the administration, others are not. On one hand there are some risks faced by the inhabitant, with immediate and evident consequences. On the other there are some potential risks, not so evident to the user. This is the case of the regulations facing aspects like fire safety or energy efficiency. The user may be aware of the risk, but he thinks he can probably manage it in some way.

Addressing the climate change through building regulations and control is a very difficult task for many reasons. It is a fragmented process where different stakeholders come into play, seems to be manageable by them and has long term consequences for the environment, not directly for the building user. It becomes therefore, as has been commented, an open gate for responsibility dilution (2013).

## 2. Current sector situation

Unless the Building Code was approved in a period of a very important building activity growth, the economic crisis started a year later, in 2007, and its impact in the country economy and especially in the building sector was lethal. Data offered by the Ministry of Fomento (2016), in Table 1, reveal two very important facts. The first one is the significant drop of the building activity, affecting especially the new buildings, which in 2014 represented only a 10% of the 2006 number. The second one is the growing importance of the rehabilitation works, that over passed the new ones in 2012.

*Table 1: Number of Buildings according to work type 2006-2014*

	<b>2006</b>	<b>2007</b>	<b>2008</b>	<b>2009</b>	<b>2010</b>	<b>2011</b>	<b>2012</b>	<b>2013</b>	<b>2014</b>
<i>new</i>	230.044	187.147	93.678	51.744	44.781	38.973	28.956	24.052	22.594
<i>to rehabi- litate</i>	35.856	33.359	34.807	33.267	31.910	30.237	29.154	25.227	26.136
<i>to demolish</i>	28.480	26.141	14.573	7.984	8.084	7.295	6.941	5.725	5.279

A third important aspect is the weight of the housing dwellings in the total property stock. According to data shown in Table 2 from the Observatory of Housing and Ground (2014), referred to September of 2013, and revealing the current number of properties in Spain (Navarre and the Basque Country not included, but specific data from these two autonomies, based on buildings and not in properties, are consistent), two thirds of the total building properties are housing dwellings (66,1%).

*Table 2: Number of properties, by use and date of construction \**

	<b><i>till 1980</i></b>	<b><i>1981-1990</i></b>	<b><i>1991-2001</i></b>	<b><i>2002-2013</i></b>	<b><i>No data</i></b>	<b><i>Total</i></b>
<i>Houses</i>	11.868.582	2.938.095	3.728.153	4.496.245	111.192	23.142.267
<i>Other Uses</i>	1.700.176	1.730.705	2.734.667	3.637.819	138.611	11.895.201
<b><i>Total</i></b>	<b>15.521.981</b>	<b>4.668.800</b>	<b>6.462.820</b>	<b>8.134.064</b>	<b>249.803</b>	<b>35.037.468</b>
<i>*Data from Navarre and the Basque Country are not included</i>						

The fourth critical aspect we can conclude from the same study is that a significant percentage of this building stock (51,3% of houses, 61,9% of industrial facilities, 51% of commercial and 41,3% of offices) was built before 1980. The year 1980 is very important in Spain, because the first insulation regulation was approved in 1979. It was completely prescriptive and considered mainly transmittance through walls, roof and soil with a very poor evaluation of important parameters, like thermal bridges.

The population and dwelling census for all the Country is worked out every ten years and its evolution, according to different data from the National Institute of Statistics (1981, 1991, 2001 and 2011), shows again (Table 3) that more than 58% of the housing dwelling stock was built before 1980. It also shows the important increase in the population number between 2001 and 2011, directly linked to the important construction activity till 2007.

*Table 3: Number of housing dwellings and population, census 1981, 1991, 2001 and 2011*

	<b><i>1981 census</i></b>	<b><i>1991 census</i></b>	<b><i>2001 census</i></b>	<b><i>2011 census</i></b>	<b><i>1991-2001 Increase</i></b>	<b><i>2001-2011 Increase</i></b>
<i>Total Houses</i>	14.770.988	17.220.399	20.946.544	25.208.623	3.726.155	4.262.069
<i>Main Houses</i>	10.431.327	11.852.075	14.187.169	18.083.692	2.335.094	3.896.523
<i>Population</i>	37.683.363	38.872.268	40.847.371	46.815.916	1.975.103	5.968.545

These four evidences: activity drop, shift to rehabilitation, percentage of houses and old inefficient stock, challenge the regulatory body, intended for a period of a building expansion activity based on new designs.

### **3. Social problems are knocking at the door**

Building regulations and control cannot be aware of important social issues, especially if the ambitious European directives to face the climate change are to be met. Unemployment, fuel poverty and changing demographics are among the most influential.

Spain has currently the largest unemployment rate of the EU, a 20,9% according to 2015 data. Unless the evolution shows a slow improvement from the worst data of 25,77% in 2012, it is still far from the register of 8,26% in 2006. The unemployment rate depends directly on the building activity if we contrast it with Table 1.

Based on readily available statistical data sources – the Household Budget Survey (HBS) and Survey on Income and Living Conditions (SILC) – it is estimated that approximately 10% of the Spanish households (equivalent to 4 million people) were in fuel poverty as of 2010. This estimate is based on two widely recognized measuring approaches, which consider that a household is in fuel poverty when spends a disproportionate share of its annual income (more than 10%) on energy or states to be unable to keep its home adequately warm in the winter. The crisis is not only making the number of fuel poor households and unemployed people grow; it is also increasing at a fast pace the proportion of unemployed households that are in fuel poverty.

According to the Projection of the Spanish Population (2014), represented in Figure 1, if the current demographic tendency is maintained in the future, Spain will lose a million inhabitants in the next 15 years and 5,6 million in the next 50 years. The percentage of the population exceeding 65 years, actually an 18,2%, will raise to 24,9% in 2029 and to 38,7% in 2064

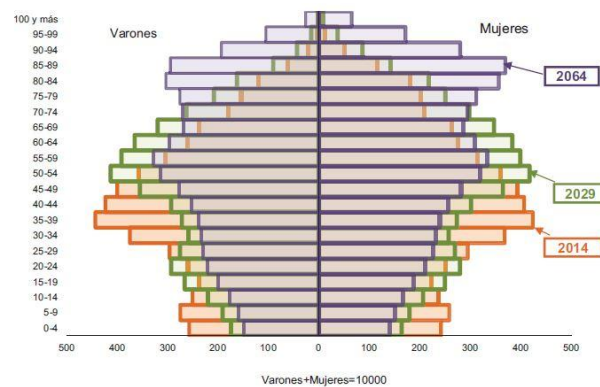


Figure 1: Projection of the demographic pyramid, 2014-2029-2064, by gender

These three problems will be important drivers in a near future. If unemployment and fuel poverty persist, there won't be money for maintenance and refurbishment and the demographic change will avoid the necessity of new structures.

## 4. Current regulatory situation

The Building Act picked up the six essential requirements that a building had to meet according to the European Directive of Construction Products (1988) (89/106/EEC). Between them, the "Energy economy and heat retention" requirement stated that the construction works and its heating, cooling and ventilation installations must be designed and built in such a way that the amount of energy required in use shall be low, having regard to the climatic conditions of the location and the occupants.

Starting from its first version in 2006, the Building Code, in its document "Energy Saving" (DB-HE), has been increasing the saving requirements in order to transpose the different European Directives. The last one, in 2013, has been oriented to the achievement of the European Union 20-20-20 objectives and partially transposes to the Spanish legal body the Directive on the Energy Performance of Buildings (2010) (2010/31/EU), in relation to the requirements of energy efficiency in buildings established in articles 3, 4, 5, 6 and 7, as well as the Directive (2009/28/EC) on the promotion of the use of energy from renewable sources, established in article 13 (2009).

Between other aspects, it regulates:

- The primary **consumption** of not renewable energy sources for heating, cooling and hot water production in new buildings. The energy rating for the primary non-renewable energy consumption indicator of a new building or an addition to an existing one is required to have an efficiency rate equal or superior to B. In uses different than housing, it includes lighting.
- It limits the energy **demand** for new buildings (in some climate zones, this implies a double thickness of the insulation materials than the considered in the first Code version).
- The performance of the thermal systems is improved.

- The performance of the lighting systems is improved, limiting their maximum installed power and establishing control procedures for natural light use.
- The minimum solar contribution for hot water production is required to new buildings or those where the use is changed with a hot water demand exceeding 50l/day. It is also extended to existing buildings with a hot water demand exceeding 5000l/day, if this over passes by 50% the previous demand.
- The minimum Photovoltaic contribution is extended to new or existing buildings where a global rehabilitation is carried out with a surface exceeding 5000 m<sup>2</sup>.

In 2011 the regulation laying down harmonised conditions for the marketing of construction products and repealing Council Directive 89/106/EEC was approved (2011) (Regulation (EU) N° 305/2011 of the European Parliament and of The Council). A new essential requirement appeared: sustainable use of natural resources. According to it, the construction works must be designed, built and demolished in such a way that the use of natural resources is sustainable and in particular ensure the following:

- a) reuse of recyclability of the construction works, their materials and parts after demolition
- b) durability of the construction works
- c) use of environmentally compatible raw and secondary materials in the construction works

This requirement is still under development as to be applied to the buildings. It is applied to products at a level of ecological labelling (environmental labels type I and III), but is voluntary.

## 5. Current control situation

Two are the instruments adopted to fulfil the EU objective of improving energy efficiency by a 20% by 2020:

- Energy Certification is a requirement derived from the 2002/91/CE and the 2010/31/EU Directives, partially transposed to Spain by the Royal Decree 235/2013 (2013). It is the main tool to evaluate the consumption of non-renewable primary energy, expressed in kWh/m<sup>2</sup>, and the CO<sub>2</sub> emissions, expressed in KgCO<sub>2</sub>/m<sup>2</sup>year, and establishes the building energy performance.
- Energy Audits are regulated by Royal Decree 56/2016 (2016), which derives from the 2012/27/EU Directive. It aims to promote actions that may contribute to savings in primary consumed energy as well as to optimize the energy demand of installations, equipments or systems of big enterprises (not SMEs).

## 5.1 Energy Certification

Energy Certification is compulsory for new buildings, existing buildings that are sold or rented and buildings or building parts run by a public authority with a surface exceeding 250 m<sup>2</sup> and frequented by the public.

The government has developed free computer tools for certification, both for new and existing buildings, has approved the energy efficiency certificate model and has set the label. The scale results from dividing the emissions and primary energy consumption of the building by the ones of a reference building. In the case of new structures the reference building meets the building code requirements and in the case of existing buildings it meets medium values of the existing stock. It is very complicated to offer a translation between the energy savings and the letters, because it depends on the building type, year of construction, location, etc.

The certification system lays on the reliability of the modelling tools and, for the moment, post-construction testing is not required. The reality shows a big GAP between what is simulated and the reality.

In new buildings, the certification stays at the project level and some evidence through testing should be important in the future to guarantee the calculated values. Air infiltrations, for example, may be responsible for a 30% of the consumption in a linear block typology built before 1979. They depend on the execution of the work, the joint solution between the window and the façade or the window permeability to air. Air infiltration testing could be carried out only in the more representative and critical dwelling units, taking into account orientation, floor level and exposure to wind. Thermal bridges could also be detected by using thermographic cameras.

In existing buildings, the calibration software tools allow the use of many default values, if the real ones are not known, to characterize the building envelope, allowing the GAP to be substantial. In order to reduce it, a previous energy performance monitoring campaign (temperature and humidity sensors, thermofluxometries, infiltration tests and thermographies) could help to have a more accurate diagnosis and, consequently, guarantee the effectiveness of the rehabilitation measures. Some post construction tests, like the ones in new buildings, should be proposed.

Table 4 shows the number of certified and registered buildings at 31 of December of 2014 (2015) and reveals that only one percent of them correspond to new buildings.

*Table 4: Number of Energy Certificates by Autonomous Community*



<i>Autonomous Community</i>	<i>Number of certificates New Buildings</i>	<i>% of certificates New Buildings</i>	<i>Number of certificates Existing Buildings</i>	<i>% of certificates Existing Buildings</i>
<i>Andalucía</i>	1.040	7,91%	147.204	12,98%
<i>Aragón</i>	33	0,25%	8.863	0,78
<i>Asturias</i>	52	0,40%	8.474	0,75%
<i>Baleares</i>	268	2,04%	28.464	2,51%
<i>Canarias</i>	150	1,14%	16.900	1,49%
<i>Cataluña</i>	2.030	15,44%	332.588	29,33%
<i>C. Leon</i>	207	1,57%	42.912	3,78%
<i>C. Mancha</i>	35	0,27%	24.545	2,16%
<i>Extremadura</i>	3.015	22,94%	1.072	0,09%
<i>Galicia</i>	150	1,14%	38.413	3,39%
<i>Murcia</i>	221	1,68%	26.202	2,31%
<i>Navarra</i>	775	5,90%	16.737	1,48%
<i>País Vasco</i>	285	2,17%	28.454	2,51%
<i>Rioja</i>	59	0,45%	8.847	0,78%
<i>Valencia</i>	4.578	34,83%	201.586	17,78%
<i>Madrid</i>	239	1,82%	197.332	17,40%
<i>Cantabria</i>	8	0,06%	5.372	0,47%
<b><i>TOTAL</i></b>	<b>13.145</b>	<b>100%</b>	<b>1.133.965</b>	<b>100%</b>

These data, considering the problems to characterize the existing buildings, present a crude evidence and especially if combined with the ones in Table 5, which show the amount of certificates for each rating letter.

*Table5: Emissions, new and existing buildings*

	<b><i>A</i></b>	<b><i>B</i></b>	<b><i>C</i></b>	<b><i>D</i></b>	<b><i>E</i></b>	<b><i>F</i></b>	<b><i>G</i></b>	<b><i>Total</i></b>
<b><i>Emissions new</i></b>	761	950	1.489	4.338	5.406	66	135	13.145
<b><i>Emissions existing</i></b>	1974	7109	39.244	133.938	522.085	147.325	282.290	1.133.965

The biggest percentage of certificates corresponds to existing buildings and is rated in the worst categories (E, F and G), very far away from fulfilling the B requirements.

## 5.2 Energy Audits

Energy Audits are compulsory for enterprises with more than 250 employees or a turnover exceeding 50 million Euros and a total balance sheet over 43 million Euros. The energy audit, every four years, has to cover at least an 85% of the final energy total consumption in the national territory.

The objective of the audits is to establish a diagnosis of the building actual performance in relation to energy efficiency and to establish the improvement measures to diminish the building energy consumption. As the emissions are also considered, the type of combustible is important.

The Decree establishes that the audits should be based on up-to-date, measured, traceable operational data on the energy consumption and, in the case of the electricity, on load profiles. They have to comprise a detailed review of the energy consumption profile of buildings or group of buildings, industrial operations or installations, including transportation. They shall allow detailed and validated calculations for the proposed measures so as to provide clear information on potential savings.

## 6. Working with building typologies for existing buildings

Working with typologies has proved to be a good tool to understand the performance of existing buildings. A research study carried out by us selected the most common ones built between 1940 and 1980, a period of big expansion and poor energy performance. This allows establishing rehabilitation measures for building typologies with common architectural and construction features, and not for single buildings.

Through the monitoring of a representative sample, the current energy demands are simulated for the different typologies and different rehabilitation scenarios and intervention levels are proposed to diminish the demand. By doing this, data on most influential energy saving parameters are suggested (Figure 2).

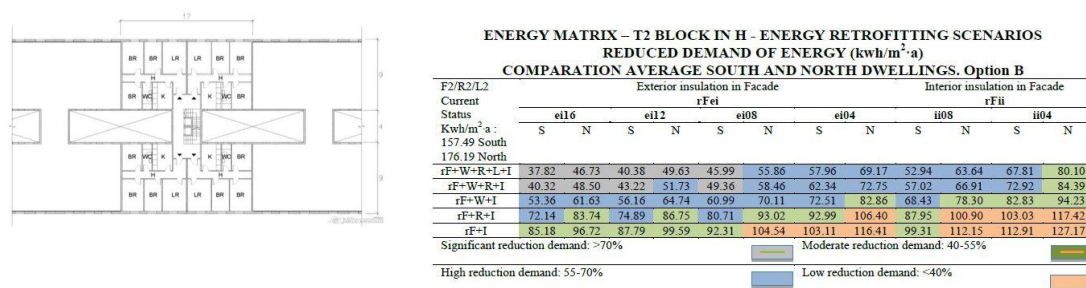


Figure 2: Typology and decision matrix based on different rehabilitation scenarios

Typologies are useful to define usage patterns too, because they can help to characterize the users by means of their social, working or economic characteristics. This is important because there is another important GAP between what is proposed by the regulations in relation to the buildings use and the reality. In some buildings, especially in those with individual systems, the use of heating and the set point temperature differs considerably from the conditions established for calculating the energy demand.

## **7. Discussion**

The relation between buildings and climate change is of double sense. On one hand, the buildings account for 40% of total energy consumption in the EU, therefore being one of the main contributors to greenhouse gas emissions. But on the other, they will be potentially menaced in a future by important natural threats. Temperature rising will demand for more cooling energy, air quality deterioration will ask for more sophisticated ventilation and statistically unexpected rains or winds will challenge the structures and the building systems.

Building regulations in Spain include among their objectives a rational use of the energy and fossil fuels and seem to have a performance structure capable of facing the climate change problem. However, they are emphasizing a model based on documentation fulfilment, which finally works as a prescriptive one with very poor results. The regulatory body is tough for the stakeholders with several authorities having jurisdiction involved.

Important economic and social problems added to the fact that the existing structures will continue representing, by far, the biggest percentage of the stock, will not allow having a significant percentage of energy efficient buildings if things do not change.

## **8. Conclusions**

- The structure of the regulatory body in Spain was designed to give adequate answer to the different building objectives and essential requirements. The rational use of energy is among them and is currently addressed through certification and audits. The use of natural resources (materials), according to the seventh requirement for construction works (Regulation (EU) N° 305/2011), under the point of view of LCA, is to be addressed as soon as possible.
- Important facts like the activity drop (and increasing rehabilitation), the existing building stock (mainly houses with very poor performance), combined with serious social problems are challenging this potentially adequate structure.
- Data on the certification process show that the system is failing, because almost all the certificates correspond to existing buildings with very poor performance rate. Their results are additionally very uncertain.

- An important change considering less regulations, more design flexibility, improving education, a real risk characterization and more emphasis on the responsibilities of private parties is to be addressed.
- The existing building stock needs to be faced specifically with different strategies and tools, not as a particular case of the new ones. Typological studies may help in this task.

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# Interstitial emergence for green building: The emergence of green building practices and assessment schemes

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## Abstract

The overall progress towards sustainability in the built environment has been repeatedly criticized for being slow, patchy and failing to have any significant impact. Over the past 20 years, a myriad of environmental assessment schemes have emerged to aid the adoption of green building practices in the construction industry. While these schemes have been touted as steering the drive towards sustainability the framing of the concept “green building” has been criticized for not resonating with industry professionals; with a chasm existing between practices codified in the schemes and what is technically possible and expedient. This paper sets out to explore the emergence of building environmental assessment schemes – how they are created and developed, and which actors influence the contents. The point of departure is that how assessment schemes are developed affects the content, and in turn various actors’ ability and willingness to engage with them. Drawing on the field-based theory proposed by Fligstein and McAdam and the concept of interstitial emergence, we explain how green building practices have emerged in the building industry. We explain how a field/interstice for green building has appeared as industry actors engaged in various strategic actions in response to the budding green building movement. As this field emerges, and actors begin to make sense of the green building concept, various frames, templates or guidelines are developed to codify emerging new practices. The fluidity of the green building concept and the heterogeneous nature of professional practices means that actors may have varied conceptualizations of green building. The challenge in the development of schemes is, thus, the operationalization of the concept ‘green building’ to resonate with the various professional actors in the industry. We posit that, the development of schemes must consider issues of cognitive and normative legitimacy in order to garner the support of professional actors. We conclude by making a case for the need to empirically explore the role of industry professional and other actors in the establishment of Building Environmental Assessment Methods (BEAMs).

**Key words:** Green building, building environmental assessment methods, interstitial emergence, field theory

## 1.0 Introduction

The movement for a shift from conventional building practices, which has been labelled “green building,” is an attempt to move towards a more sustainable built environment. Green building emerged in the 1990s as various industry actors - specialists, practitioners, researchers, professions, academic institutions and various other organizations – started to look for ways to decrease the impact of buildings on the environment (Cole, 1998). Since its emergence the term has become ubiquitous as a label for buildings which are deemed environmentally friendly. Some proponents have gone as far as touting the concept of green building as the future of building construction, and the way forward for the entire built environment. Its emergence is viewed as seemingly changing the underlying social structure in the building industry, and it is heralded by some as creating a shift in how buildings are designed, constructed and operated; challenging centuries-long practices in the industry (cf. Henn and Hoffman, 2013). Until recently such assertions have stood unchallenged and little research has focused on exploring if this changing socio-cultural context in the building industry is actually taking place.

With the emergence of Building Environmental Assessment Methods (BEAMs), and the stark reliance on them to set green building standards, much hope has been put on their use as instruments of change in the building industry. BEAMs have become common in the building industries of most developed countries, and are increasingly being used by policy makers and industry stakeholders to help drive sustainable development in the built environment (Schweber, 2013; 2014). In view of their widespread use as a vehicle for propagating green building practices, various research works have been carried out to ascertain how efficiently they conceptualize the concept “green building.” These works have explored the technical features of BEAMs (e.g. Crawley and Aho, 1999; Cole, 1998; Cole, 1999; Cole, 2005), and have sought to compare the various sustainability indicators, weightage and the ratings of BEAMs. Some researchers have also moved on to explore whether the adoption of BEAMs is even influencing green building practices in the industry. Some of these works have investigated whether BEAM adoption influences routine green building practices in the industry; and whether it is aiding a change in, and/or influencing professionals and professional practices in the industry. Some have also explored whether the adoption of BEAMs is aiding the creation of green building awareness among industry professionals (Thomson, et al., 2010) and the effect BEAMs are having on construction projects (Schweber and Haroglu, 2014).

While this growing body of research work has investigated events after the development and establishment of schemes in the industry, an area which has received little attention in the academic literature is events at the nascent stages of green building emergence; before the establishment of BEAMs. Exploring these events will not only offer insight into how industry professionals engage with, and adopt these assessment schemes, but also how their actions contribute to the failure or success of implementing them. There is the need to understand how BEAMs are used to give content to the green building concept (Schweber, 2014), i.e. how they are developed, and industry actor’s reactions to the practices codified in BEAMs. Exploring this will depend on an understanding of how green building practices emerge, and which actions are taken to ensure that practices codified in schemes resonate with industry professionals. This paper takes a cue from this argument, and going back in time to the point of origin, explore the concept of green building, its emergence in the industry, and how industry actors went about the process of ‘making sense’ of the concept to define which practices are ‘green’ and which ones are not. In so doing, we seek to add to the growing body of academic research which has begun exploring the sociological aspects of green building, employing theories from the social sciences to explicate the evolving and changing social structures in the building industry and the role of BEAMs in this process (e.g. Holmes and Hudson, 2002; Boyd and Schweber, 2012; Schweber, 2013; Schweber, 2014).

The paper draws on the concept of interstitial emergence (Morrill, 2006) and the field-based theory proposed by Fligstein and McAdam (2012). The argument made is based on the assumption that the emergence of green building can be viewed as the introduction of new institutional logic(s) in the building industry, and the establishment of BEAMs offers an example of how new action frames are introduced to reify this new logic(s) and alleviate “ontological anxiety.” These frames show actors which actions are legitimate and reflects the cultural understanding of what actions make sense based on actors’ subjective interpretation of green building. The following sections, first and foremost, explore the emergence and development of Building Environmental Assessment Method (BEAMs) in the industry. The concept of interstitial emergence, taken from institutional analysis, is then introduced to provide a theoretical edifice to explain the role of industry professionals in the emergence and development of BEAMs. This section explains the emergence of a common domain where actors operating in different professional jurisdictions congregate to define new standards based on their shared understanding of the concept of green building. This helps to explicate the role of actors in giving content to the concept ‘green building;’ and how they engage in various actions to promote practices and support the development of schemes. The paper concludes with reflections on the role of industry actors in the emergence of the green building sector and the development of assessment schemes.

## **2.0 Building Environmental Assessment Methods**

Building Environmental Assessment Methods/Schemes or “green building guidelines” have emerged to help categorize the vast range of environmental criteria that are relevant to buildings. They provide a means for designers and builders to identify and specific environmental criteria depending on the needs of clients. These schemes have evolved out the need for a holistic comprehensive methodology to ascertain the environmental impact of buildings; providing a platform to outline green building practices. They offer a way for industry actors to objectively assess the environmental performance of buildings. Developed to set a standard for green building (Schweber, 2014), they lay down a direction for the industry to move towards environmental protection and achieve the goal of sustainability (Ding, 2008).

Aside having environmental assessment as its core functions, BEAMs may be accompanied by some form of third-party registration or certification. The certifications indicate the extended outputs from the assessment process. These typically take the form of a singular, easily recognizable designation, e.g. ‘Gold’, ‘Excellent’ or number of attained ‘Stars.’ The first assessment scheme, the Building Research Establishment Environmental Assessment Method (BREEAM), was established by the UK Building Research Establishment in 1990. Since its establishment, numerous assessment schemes have been developed. Aside influencing the development of LEED in the US, BREEAM has also made an impact worldwide, with Canada, Australia, Hong Kong and other countries using the BREEAM methodology to develop their own building environmental assessment methods (Ding, 2008). Most developed and rapidly developing countries now have their own domestic assessment schemes and many other developing nations are in the process of localizing existing assessment schemes for their local construction industries (Du Plessis and Cole, 2011). These schemes are constantly updated, and new version are developed to meet changing market demands and environmental expectations. For example, in response to the Copenhagen Summit in 2009, HK-BEAM Society, the owner of HK-BEAM in Hong Kong, introduced a new version of the assessment scheme – HKBEAM-Plus Version 1.1. Introduced in April 2010 (BEAM Society, 2010), and in response to the conference agenda, this version of the scheme placed greater emphasis on the importance of greenhouse gas emission reductions.



Efforts by most countries to develop their own domestic scheme is motivated by the need to encourage green building practices appropriate to specific climatic and cultural contexts. In most cases, various technical committees, advisory groups, industry experts and consultants are engaged in developing new and updated versions of schemes. Usually, they are developed to meet specific industry objectives, which are usually influenced by national sustainability goals. However, in a rapidly globalized world, the localization of assessment schemes creates complications for stakeholders, including property investors, who purchase buildings in different countries (Ding, 2008), or who are involved in the development of multi-national project. This has led to increasing use of some international brand name assessment schemes such as the US-LEED and UK-BREEAM. Their presence in the local market of some countries is largely due to the demands for 'brand recognition' in a global market and the motivation of the owners of some assessment schemes to expand the adoption of their assessment schemes abroad.

## **2.1 The organizational Context of Assessment Scheme**

The establishment of the majority of assessment schemes (e.g. LEED, BREEAM, and HKBEAM) are defined by the current neoliberal zeitgeist that embraces government at a distance. As such they are voluntary in their application (Ding, 2008; Du Plessis and Cole, 2011), and they are mostly owned and promoted by industry or other non-state actors (e.g. NGOs). There are also a number of voluntary schemes which have been developed and are owned by the government/or state actors. For example NABERS, the Taiwanese Evaluation Manual for Green Buildings (EMGB) and the Hong Kong CEPAS. The distinction between voluntary and mandatory assessment schemes is that, unlike mandatory schemes such as the Singapore Green Mark and the Australian Building Sustainability Index (BASIX) which specify minimum certification requirements and are increasingly being used as incentives for development approval, voluntary schemes (e.g. Hong Kong BEAM and the US-LEED) are initiated and administered by industry or non-state actors who may not have the authority to impose any strict regulations regarding their adoption.

Considering the voluntary nature of majority of the schemes, the issue of how to promote their adoption and encourage engagement by industry professionals becomes key. Whereas building professionals may have no choice but to respect assessment schemes that are mandated, they are less constrained with regards to the adoption of voluntary schemes. Thus, a central argument with voluntary schemes concerns the conditions under which they are adopted or challenged by professional actors. Since these schemes promulgate a particular understanding of "green building", professional actors can challenge the content if they do not agree with how green building is conceptualized in BEAMs. The emergence of terms such as "sustainable building", "High performance building", "smart building", "environmentally friendly building", which have all become synonymous with the concept of green building (Henn et al., 2013), evoke various actors interpretation of what green building should accomplish, or the goal of green building. The challenge in the development of assessment scheme is therefore the operationalization of the concept "green building." This is because, aside the challenge of codifying the numerous environmental criteria, deciding on which practices are 'green' and which ones are not, and which indicators and weightages to use, is not an easy task. To overcome this challenge of operationalizing the concept such that it resonate with the industry's myriad actors, some schemes use open-ended language to frame practices. With such variability in the concept, the development of assessment scheme to codify green building practices is sometimes fraught with struggle over how the concept is framed in assessment schemes.

In the UK for example, increasing rejection of assessment criteria in BEAMs as authentic measures for green building has been reported (See Schweber, 2013, 2014). Professional actors criticized particular credits or categories for not adequately, or wrongfully capturing the green building concept. These concerns

question the authority of developers and owners of these schemes and impedes the adoption of green building practices and the advancement of sustainability in the building industry. Considering the heterogeneous nature of professional practices in the building industry, a vital question in the development of BEAMs is how to conceptualize the knowledge of green building into meaningful practices that resonate with actors from varied professional backgrounds, with varied ideologies. And how multiple types of technical knowledge of the various experts engaged in the development of schemes can be combined to develop a scheme that resonates with professional actors operating in different professional jurisdictions and with different values and principles.

Thus, if professionals from different disciplines are to coalesce around a particular universal definition of green building and develop a shared sense of identity and purpose to help promote green building practices (Bresnen, 2013), the question is how such a united front can be forged around a single assessment scheme. And how can such a collaboration be achieved if industry professionals have different perspectives of what green building is, and which practices qualify as 'green' and which ones do not? The next section sheds some light on the heterogeneous nature of professional practices in the industry.

## **2.3 The nature of professional practices in the building industry**

The shift towards sustainability in the built environment will require some form of engagement among industry actors in order to develop a more holistic solution. Since green building, as noted by Hughes and Hughes (2013), does not really fall into any professional jurisdictional domain, it requires a range of collaborative engagements across various professional domains in the industry. Some researchers have advocated for the development of a new sense of professional ethics (Hill, et al., 2013), and have questioned the ability of professional institutions to separately provide the needed drive to respond to environmental concerns. However, professional actors in the building industry operate in different jurisdictions (Bresnen, 2013), developing their own set of skills, knowledge base, and working on their own tasks. Actors in the building industry seldom interact, and the one-off bespoke nature of construction projects exacerbates the heterogeneous nature of professional work. This fragmentation makes promoting green building and specifically BEAMs in the industry anything but a trivial task.

Bresnen (2013) stresses the need to address competitive, collaborative and participative challenges that inhibit forging a united front to address sustainability concerns. Some researchers have argued for the need for professional actors to develop a shared sense of identity and purpose (e.g. Hartenberger, et al., 2013; Duffy and Rabeneck, 2013). Some (e.g. Twinn, 2013) have even called for building professionals to act as a united voice and use media outlets to communicate messages about green building. But as Bresnen (2013) points out, this leaves open the question as to how such a united voice might be created and mobilized. Mobilizing actors from different jurisdictions to promote specific sets of green building practices presents a variety of issues; such as which alternative practice should be promoted. Since actors will have varied perspectives on what green building is and how best to achieve it, there is always the challenge and risk of attempting to instill and impose unitary notions of accepted practices.

It follows from the above that the development and establishment of assessment schemes have to take into account how actors with varied professional backgrounds negotiate the meaning of green building and develop a shared sense of identity around a particular scheme. Addressing the issues of legitimacy of schemes also becomes problematic considering the varied technical background of professionals and the fact that each professional jurisdiction has its own institutional norms and values. Coupled with this is the presence of professional bodies who may want to preserve tried and tested ways of doing things. While

preserving their exiting professional identity, these professional bodies may want to take on new professional roles vis-à-vis the emergence of green building. These observations present a challenge when one considers the voluntary nature of most assessment schemes and the fact that professional actors who do not agree with the meaning of green building may resist their propagation as genuine measure of green building (Schweber, 2013, 2014).

### **3.0 Conceptualization of BEAMs in the Building Industry**

It is difficult, if not impossible, to provide a universal definition of Green building. It is better understood as an emergent concept. The concept is in constant flux, shifting as actors who represent different social groups or fields in the industry engage with each other to negotiate its meaning. Thus, green building practices codified in BEAMs are subject to considerable debate and simultaneous multiple meanings (Howard-Grenville et al., 2007). It follows that, at every stage in the evolution of green building in the industry, it is possible that differentially powerful actors will influence the framing of the concept, with each actor espousing and promoting different practices – practices which possibly advance their own interests in the industry (Fligstein and McAdam, 2012). The fluidity of the concept means that multiple interpretations will constantly be at play, competing for dominance as actors negotiate the meaning of green building. As stated above, the nature of professional practices means that different professional actors operating in different professional jurisdictions (see Bresnen, 2013) may hold different views about the concept ‘green building.’ Even professional actors in the same professional jurisdiction may have different subjective interpretations of what green building means to them or their organization. Thus, at the level of practice and implementation, the variously held subjective interpretations can translate into political contestation over the multiple meanings and means of adopting green building. Thus, the development of assessment schemes can be seen as fraught with power struggles among industry actors; as to who wins and who loses in the debate over which standards and practices become adopted (Janda and Killip 2013).

Based on this argument, assessment schemes should be viewed as the outcome of negotiated shared meanings/understandings of green building. Their emergence in the building industry should be viewed as the development or creation of a universal template that provides an interpretive frame for multiple actors situated in different professional fields in the building industry. These schemes embody the knowledge and practices of the industry. They therefore function as knowledge repositories, standardized forms and methods used to communicate across multiple fields; translating and transmitting knowledge across multiple fields. Understanding how actor, with varied interests and goals, go about the process of developing such a scheme is the focus of the theoretical position elucidated in the next section.

To make this theoretical argument, the building industry is conceptualized as a social space in which relatively large number of individuals and organizations, who may belong in different fields/jurisdictions, engage with each other. Industry actors occupy various organizational fields, with each field comprising aggregates of organizations/professionals/actors providing similar services, their constituencies, and their relevant professional bodies (DiMaggio and Powell 1983). These fields exists together with numerous other state and non-state fields and are nested within each other in a broader field environment. Industry actors operating in various fields or professional jurisdictions interact with each other on the basis of shared (but not consensual) understanding about what is at stake in the industry (in this case, the delivery of green buildings). Actors relate with each other with a shared understanding of the rules governing legitimate actions in the industry vis-à-vis green building. Through this process of engaging with each other, taking each other’s actions into consideration as they produce green buildings, actors are attempting to create and sustain a social world by securing the cooperation of others. They do this not only to take advantage of

emerging new ideas, by behaving strategically to advance their individual interests in the industry. Actors also consider the benefit of a collective identity, of being part of a social group – the green building field – what Fligstein and McAdam (2012) labelled as “the existential function of the social.”

### **3.1 Interstitial emergence: The emergence of a green building field**

The concept of interstitial emergence is founded on the argument that firms, organizations or industry professionals are simultaneously members of multiple, partially overlapping fields (Morri, 2006; Hoffman and Ventresca, 2002). This means that when an issue (for example, reducing environmental impact of buildings) that is of common interest to actors belonging to these multiples fields arises, there will be interstices between fields (Rao *et al.*, 2000). It is at these interstices that alternative practices of building have emerged and schemes have been developed to help reduce the negative impact of buildings on the environment. What this means is that, actors, instead of addressing environmental concerns in their own professional jurisdictions or fields by expanding on existing logics and norms in their fields, will act by bridging between multiples firms to address this issue. This interactions between multiples fields leads to the emergence of a neutral arena, an interstice – a gap in social space, where alternative courses of action will be established.

Actors do not leave their professional jurisdictions, nor ignore their position in their field and move into the emerging new field. Instead they engage deliberately with different actors from other fields who are also interested in addressing these environmental concerns. The challenge for industry actors in such a situation is to remain credible in their own field, upholding the standards and norms in their professional jurisdictions, while simultaneously building resources, new capabilities and legitimacy in the emerging field. Thus, interstitial spaces are characterized by institutional diversity as actors bring with them different institutional logics from the respective fields in which they have been historically socialized (Furnari, 2014). As a result, actors interacting in interstitial spaces are likely to have diverse and sometimes conflicting logics of action, taking on different identities as they traverse multiple organizational fields. They therefore face the challenge of managing the conflicting logics in their own fields and the new logics in the emerging field.

Morrill (2006) identified three mechanisms that leads to the emergence of a legitimate social space, i.e. a new field, for emerging new practices in interstitial spaces: 1) the development of resonant frames for the new practices, 2) mobilization of critical masses and resources in support of these frames, and 3) structuration efforts. What this means is that, before the development of any formalized script or universal template of action (i.e. BEAMs) in any industry, various alternative practices would have already started cropping up in the industry and these might have been implemented sporadically and informally on construction projects. Since actions at this stage of field emergence are informal and are not guided by any formal institutional script (cf. Rao *et al.* 2000), such practices may not be adopted by other actors. Practices advanced by individual actors will be based on their own ideology (Benford and Snow, 2000), infused with shared meanings reflecting their cultural beliefs and norms (Furnari, 2014). As such, practices before the development of an official assessment scheme may not resonate with other actors in different fields in the industry. A typical example could be an architect trying to communicate a new idea to the builder, or the builder trying to incorporate a new innovative technology or practice. Actors will thus act strategically, employing various social skills to convince other actors to adopt and/or accept the new practices. At this stage of the field emergence, it is possible for individual actors or groups of actors to have their own frames, templates or green building guidelines for implementing new practices in their organization, professional jurisdiction or field.

As the actions of individual actors become increasingly interrelated, based on shared interpretations of the green building concept, individual frames will coalesce into collective action frames (Benford and Snow, 2000) and trigger collective action processes. Those actors with shared collective interpretation of green building will develop schemes to codify practice and start mobilizing other actors to support these practices. Thus, at the nascent stages of green building movement, when no formal scheme has been developed, it is possible for multiple schemes or template to exist. Various actor will have different views about how best to adopt the concept, and actors will start mobilizing various resources (economic, social, political and cultural, cf. Bourdieu (1986)) at their disposal to promote and support schemes that resonate with their core values and principles, and which advance their interest in the emerging field (Fligstein and McAdam, 2012).

Thus, schemes are developed to codify practices, which are then used to mobilize support and resources. What this means is that, in order to foster adoption and engagement by other industry practitioners, assessment schemes must resonate with actors in the diverse fields in the industry. These schemes may often suffer from technical and normative stigmas as they are propagated. This can be addressed by associating with and borrowing the technical legitimacy of science, substantive findings, and expert knowledge that support the efficacy of emerging new practices. With regards to cultural-cognitive stigma, actors propagating new practices can ensure that the new practices resonate with the values and principles of other actors in the emerging field. If actors promoting a particular alternative practice are successful in developing a resonant frame and mobilize support for this scheme, a legitimate social space will then be carved for the emerging new practices. Through these mechanisms, the new practices can become a new professional jurisdiction replete with new normative, cognitive and material boundaries (Morrill, 2006).

## 4.0 Discussion

Green building is seemingly introducing new sets of norms and standards of practices in the building industry. Its emergence is arguably creating new professional practices, altering roles in existing ones, and rearranging traditional roles and relationships among industry actors. Terms such as ‘sustainable architecture,’ ‘sustainable engineering,’ ‘sustainable procurement’ and various other related neologisms attests to the changing landscape of professional practices in the industry. In the wake of this, professional actors in the industry face the dilemma of managing multiple logics in their existing professional roles and new logics in the emerging green building field. There is therefore the question of how actors from different professional jurisdiction can find a common ground to address sustainability goals in the built environment. There is also the question of how actors can internalize new norms and standards vis-à-vis the emergence of green building (Schweber, 2013).

The development of BEAMs, which are aimed at reducing ontological anxiety by codifying the numerous environmental criteria relevant to buildings, provide a means for actors to find a common ground to promote green building. BEAMs are developed to operationalize the green building concept and to facilitate the adoption of green building practices. However, for BEAMs to achieve this goal, practices codified in these schemes must resonate with the myriad actors in the industry. Schweber (2013, 2014) noted that the challenge of BEAM development is how multiple types of technical knowledge can be combined. The fluidity of the green building concept and the heterogeneous nature of the building industry means that actors from various professional jurisdictions may not necessary agree on alternative practices prescribed by BEAMs. Thus, developing a scheme that resonates with professional actors operating in different professional jurisdiction and with different values and principles may be a daunting task. The involvement of professional actors with knowledge about sustainability will be one way of addressing this issue. In her study of the UK construction industry, Schweber (2014, pp.157) observed that the fact that some

*“professionals felt empowered to actively engage with and pass judgement on specific requirements draws attention to the distribution of scientific or technical authority across stakeholders in the assessment process.”* The involvement of actors with knowledge about green building will therefore afford a degree of technical legitimacy, which is needed to mobilize support for the adoption of practices in scheme. This will also contribute in addressing issues of normative legitimacy. The involvement of actors from diverse background in the development of schemes will ensure that practices resonate with the values, assumption and principles of professionals from different jurisdiction.

In the UK Building industry, Schweber (2013, pp 141) observed that *“the greater the individual’s expertise in a particular area, the less likely they are to accept the BREEAM operationalization of the concept.”* The study noted that *“...sustainability minded professionals... rejected the adequacy of the scheme for the achievement of genuine sustainability.”* A key finding of the research was *“the way in which tensions between professionals’ own understanding of ‘greenness’ or ‘sustainability’ and the requirements of BREEAM undermined their respect for the tool as a whole.”* Taking a cue from this observation, it could be argued that the tension between professionals’ understanding of ‘greenness’ and the requirement of the UK-BREEAM could be because the practices codified in the scheme do not resonate with professionals. This is not surprising as assessment schemes are usually developed with little or no input from industry professionals. It also serves to explain, at least partially, the lack of respect for schemes by some professionals and the rejection of *“the adequacy of the tool for the achievement of genuine sustainability.”* The lack of respect for scheme is shown in actors’ explicit criticism of categories used to reify the green building concept (Schweber (2014). This indirectly challenges the authority of developers and custodian of the assessment scheme (i.e. the Building Research Establishment (BRE)).

From the concept of interstitial emergence, the question as to whether actors will choose to internalize new logics depends on whether practices in the new field resonate with the core values of professional actors. Furnari (2014) viewed practices as “visible enactments” of shared beliefs that define the institutions of actors in a particular field or jurisdiction. They are infused with shared meanings. The shared meanings encoded into practices are informed by wider cultural beliefs shared at the institutional field level in their professions. Thus, green building practices emerging from various jurisdictions will reflect their idiosyncratic subjective interpretations of the green building concept. Consequently, incongruence between practices outlined in schemes and actors’ conceptualization of green building practices in BEAMs may not only lead to rejection of these practices as genuine operationalization of green building or sustainability (cf. Schweber, 2013), but also a conscious refusal on the part of actors to be transformed by the logics that are used to explain and define these practices.

With the increasing emergence of new professional practices, there is also the question of how existing and newly emerging professional practice domains establish clear professional jurisdictional claims (Bresnen, 2013). With regards to this, we posit that, from the perspective of interstitial emergence and the theory of fields proposed by Fligstein and McAdam (2012), professional actors may operate in multiple professional domains. Although with time actors may internalize logics in the emerging new field if those logics resonate with their core values, they maintain the logic of practices in their own field while engaging with other actors in the emerging green building field. Professional actors therefore take on different identities as they traverse multiple organizational fields. As long as logics are not congruent with actors’ core value, actors will manage conflicting logics between their own professional jurisdiction and the new professional jurisdiction; contributing to a superficial adoption of logics in the emerging new field.

## 5.0 Concluding remarks

The foregoing argument join in the chorus of the small but growing research agenda aimed at exploring the impact of assessment schemes on professional practices in the building industry. Since assessment schemes, for example the UK-BREEAM, the US-LEED, and the HK-BEAM have emerged to reify industry actors' interpretations of the principles of sustainability, and are increasingly being promoted as templates of action and as policy instruments by national governments, concerns about their legitimacy warrants in-depth studies. In this paper, we have provided a theoretical perspective on some of the probable reasons why industry professionals and other actors may choose not to actively engage with BEAMs. Not only can this lead to a superficial adoption of BEAMs by industry professionals, but the outright rejection of these schemes as authentic assessment tools for green building. While it can be argued that it was justifiable to instill or impose unitary notions of accepted practices at the nascent stages of the green building movement, at a time when professional actors had little to no knowledge about sustainability, it may not be expedient to do so now. Increasing professional expertise in sustainability means that actors may not, willy-nilly, accept practices imposed by the state or by other powerful actors in the industry.

This observation becomes even more crucial when analyzed from a global perspective in light of the increasing importation and use of assessment schemes developed from other regions. In most developing countries, governments with no existing domestic or local assessment schemes have adopted internationally recognized schemes in their local market. Even in developed countries, there is increasing use of internationally recognized schemes such as the US-LEED and the UK-BREEAM by international multinational firms. From the theoretical argument put forward in this paper, because practices may already be emerging at the nascent stages of the green building movement in any industry, and professionals may already be developing practices unique to their culture and environment, care must be taken when importing schemes developed in different context. Actors importing internationally recognized schemes must be smart about how they introduce these scheme in their local industries, taking into consideration how these practices dovetail with professional practices in the industry. If assessment schemes are developed for use in the building industry, then they must be developed to resonate with the practitioners who are supposed to use them in their daily activities.

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# Issues about moisture in residential buildings of Brazil

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## Abstract

Moisture is one of the main issues in building disorders. It can lead to microorganism's growth, discomfort, material deterioration and impact on energy consumption. In Brazil, there is a lack of assessment of the moisture risk potential in a comprehensive point of view, considering that most of the country is located in a tropical climate with important moisture sources. The current paper provides an overview on the potential risk of building moisture disorders, analysing the country differences of climate, population density, building standardization, type of construction methods and cultural issues. The main drawbacks reveal that many houses are built informally with lack of professional labor. Furthermore, the building standards do not consider the important moisture loads due to the climate and do not encourage the use of innovative techniques to deal with these issues. Climate, cultural and income differences within the country indicate there is a large potential for conducting research in Brazil on this topic with the perspectives of practical applications.

**Keywords:** moisture risk, residential buildings, Brazil

## **1. Introduction**

Moisture is one of the main issues in building construction. It can lead to microorganism's growth causing health problems, functional damage (corrosion, stain, decay), thermal discomfort, material deterioration, and change on energy consumption and power demand (Berger et al., 2015). The main sources of moisture are climate, capillarity, leakage, failure on construction process, and condensation. Moisture is a difficult issue to control, which may occur due to many factors such as insufficient air change rate, adsorption and desorption phenomena, leakages and presence of cracks.

Few research work about moisture in buildings are carried out in Brazil, but the majority are strictly academic restricted to a few research groups with limited funds. Construction pathology caused by moisture is a subject with a very few studies in the country; the ones found mostly have a case of study approach, not assessing the moisture risk potential in a comprehensive point of view, considering climate, building standardization, constructive techniques, and cultural issues influence.

The present article intend to evaluate the potential risk of moisture disorders in a cross-disciplinary approach, analysing the influence of climate, type of construction methods and cultural issues. Building standards, measures needed and challenges to improve moisture safety in the residential building sector are also discussed.

## **2. Brazil – Population and Characteristics**

Brazil is located in South America, its area of approximately 8.5 million m<sup>2</sup> is divided into five geographic regions as shown in Figure 1, and with estimated population of 204 million inhabitants in 2015. The Brazilian bioclimatic zoning classifies the country into 8 zones according to Figure 2, being the zone 1 the coldest and zone 8 the hottest. Each bioclimatic zone has relatively homogeneous climate characteristics, by considering minimum and maximum monthly average air temperatures and monthly average air relative humidity.

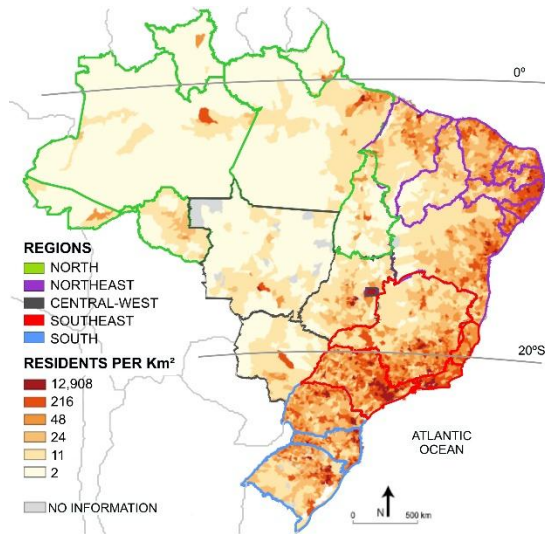


Figure 1 – Geographic regions and population density (2000)

Source: adapted from IBGE (2011)

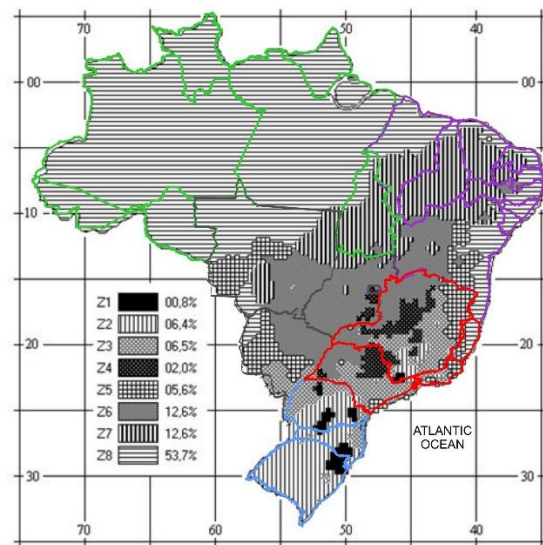


Figure 2 – Brazilian bioclimatic zones

Source: ABNT (2005)

The major population is concentrated near the east coast, and although bioclimatic zone 8 accounts for more than 50.0% of the territory it is mostly located in the region that has the lower population density. Figure 3 exhibits a comparison of land area, population, dwellings, and average monthly income per dwelling between geographic regions.

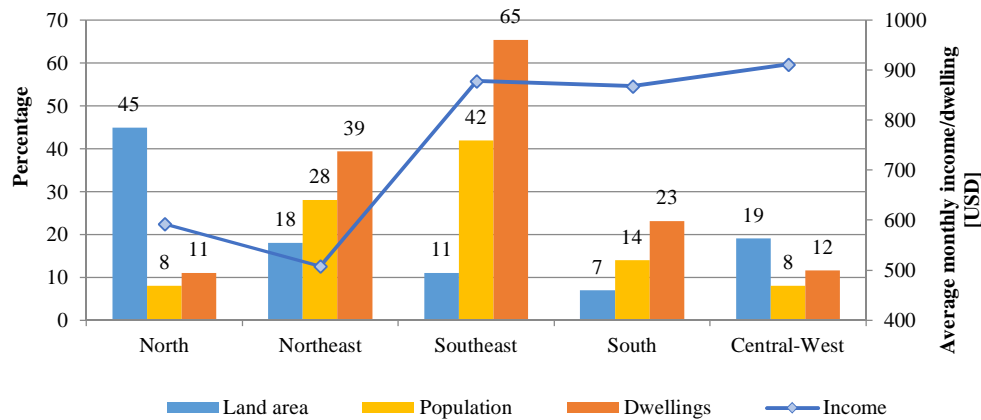


Figure 3 - Percentage of land area, population, dwellings, and average monthly income per dwelling per geographic region of Brazil

Source: adapted from IBGE (2015)

Southeast region corresponds to 11.0% of the total land area, 42.0% of the population and 65.0% of the dwellings. In contrast, the North region encloses 45.0% of land area and accounts for just 8.0% of the population and 11.0% of the dwellings. Northeast with near 28.0% of population has the lowest average income per dwelling.

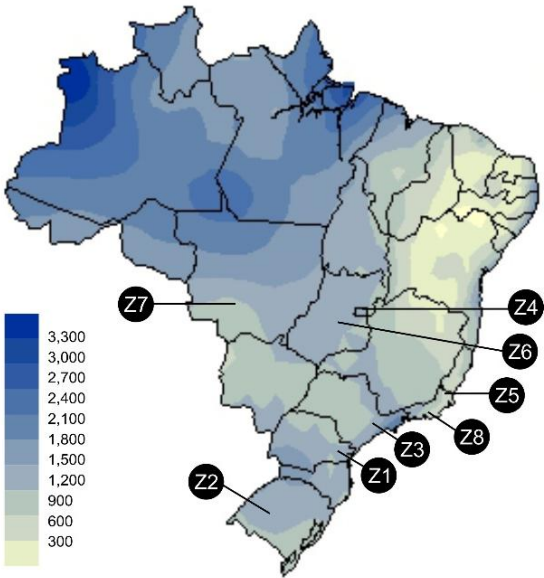
To have an overview on moisture disorder risk in Brazil, climate data for 8 cities corresponding to 8 Bioclimatic Zones are presented (Table 1). Cities were chosen according to the largest

population among the cities with data available. Figure 4 presents the average annual precipitation and the location of the cities representing each bioclimatic zone, and Figures 5 to 7 present their average monthly precipitation, air temperature, and vapour pressure. Figures 4, 5 and 7 show the high moisture disorder potential due to the high precipitation rate and to the high outdoor vapour pressure.

*Table 1 – Bioclimatic zones cities and population*

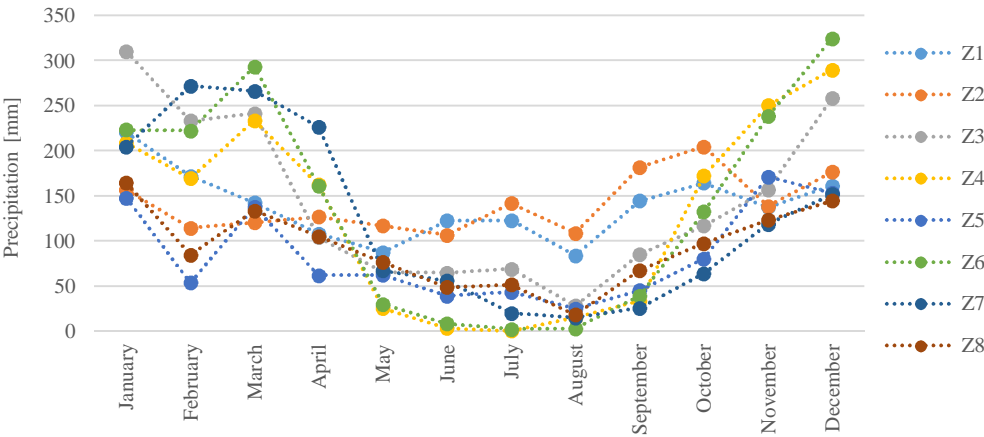
<b>Zone</b>	<b>City</b>	<b>Population</b>
Z1	Curitiba	1,879,355
Z2	Santa Maria	276,108
Z3	São Paulo	11,967,825
Z4	Brasília	2,914,830
Z5	Campos	483,970
Z6	Goiânia	1,430,697
Z7	Cuiabá	580,489
Z8	Rio de Janeiro	6,476,631

*Source: adapted from IBGE (2015)*



*Figure 4 – Average annual precipitation (1931-1990)*

*Source: adapted from INMET (2016)*



*Figure 5 – Average monthly precipitation (2005-2015)*

*Source: adapted from INMET (2016)*

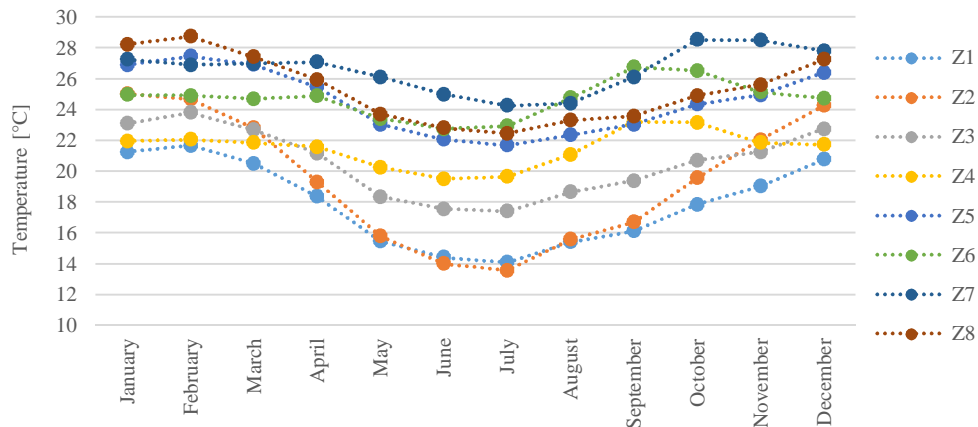


Figure 6 – Average monthly air temperature (2005-2015)

Source: adapted from INMET (2016)

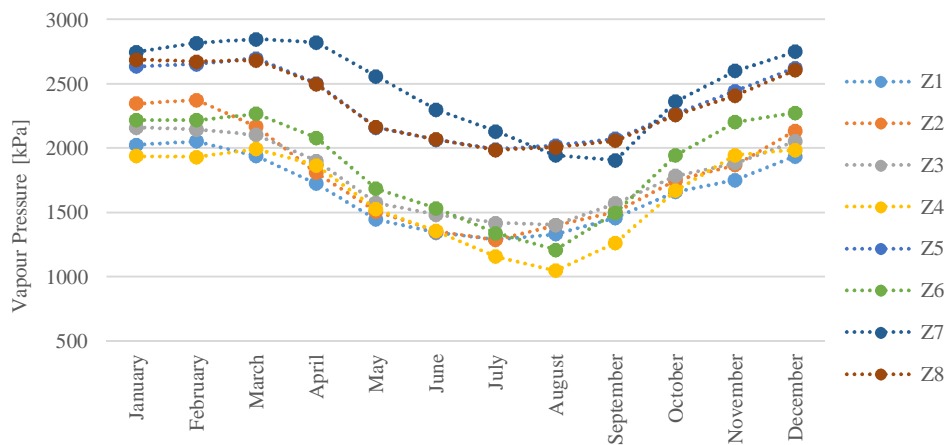


Figure 7 – Average monthly vapour pressure (2005-2015)

Source: adapted from INMET (2016)

Curitiba, which is the capital with the lowest average temperature, has the higher relative humidity values despite its high altitude. São Paulo and Rio de Janeiro, the more populous cities, have great differences between temperature but close values for relative humidity. It can be noticed that for all cities there is an outline of dry cold periods (April - September) and wet hot periods (October – March).

It can be noticed that the climate is an important source of moisture due to high precipitation rate and high outdoor vapour pressure. These climatic conditions reveal an important source of moisture that can lead to potential risks if it is not well managed. The potential mould growth risk was analysed using the isopleth limit approach (Vereecken and Roels, 2012), in which hourly outside temperature and moisture content are plotted on the psychrometric diagram. The red points indicate data of temperature and humidity ratio obtained from Test Meteorological Year (TMY) weather files; the points above the isopleth curve indicate hours of mould growth risk.

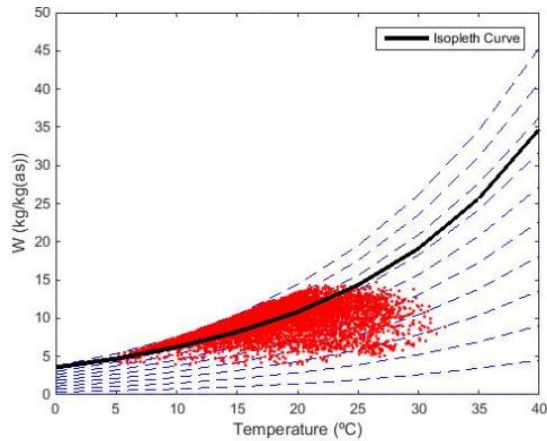


Figure 8 – Mould growth risk for Z1 (Curitiba)

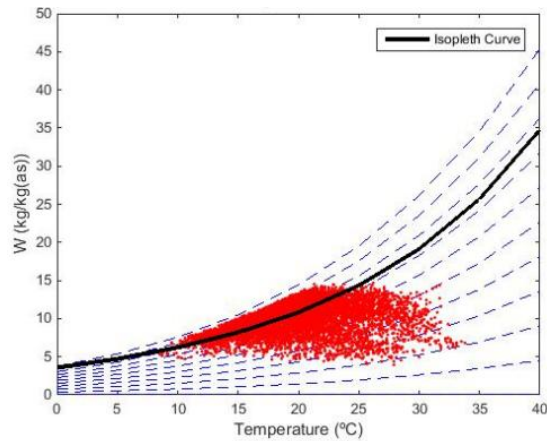


Figure 9 – Mould growth risk for Z3 (São Paulo)

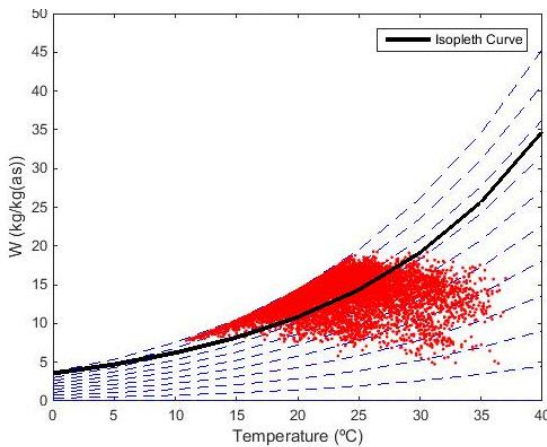


Figure 10 – Mould growth risk for Z8 (Rio de Janeiro)

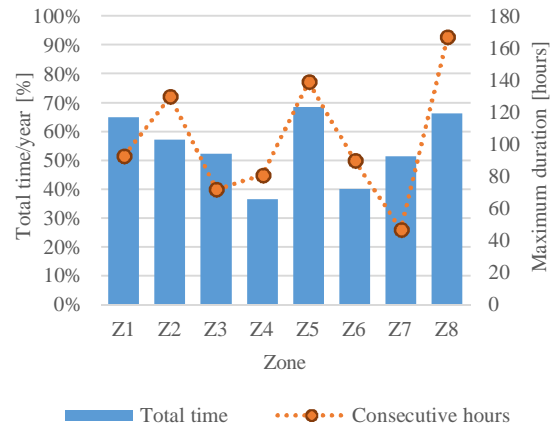


Figure 11 – Time of mould growth risk within one year per zone

With the exception of zones 4 and 6, all the others have more than 50% period of risk within the interval of one year, having zone 5 the highest value that is approximately 70%. Zone 8, in addition of having around 65% of time per year, also presents the greatest value of consecutive hours of risk (around 7 days). These data may represent an important issue considering that zones 5 and 8 encompass a significant part of Southeast and Northeast regions, the more populous ones. The outside moisture content should be managed to do not penetrate into building and lead to mould growth risk.

Despite of the geographic, cultural, and climatic differences between regions, there is few variation of constructive methods between geographic regions as presented in Table 2.

*Table 2 – Construction methods main used on single-story houses according to geographic region*

Region	Construction method	Amount of total single-story houses of the country	Absorptance	Thermal transmittance	Thermal capacity
		[%]	[dimensionless]	[W/(m <sup>2</sup> .K)]	[kJ/(m <sup>2</sup> .K)]
North, Northeast, Southeast, South, Central-West	Masonry with plaster and light colored paint	96.0	0,4	2,86	100
Northeast, Southeast, South, Central-West	Clay tile and concrete slab	62.2	0,7	2,05	238,4
North	Clay tile and wooden ceiling	28.8	0,7	2,02	26,4

*Source: adapted from SINPHA (2005)*

Single-story houses represent 88% of the total dwellings (Figure 3) (IBGE, 2015). Data from the construction industry relating type of financing (self, private, or governmental), amount of houses built by construction firms, and the total number of houses (given by official national census) gives a panorama of about 67% to 77% informally built houses (CGEE, 2009).

The main characteristic of the informally built house is the direct management of their owner and occupants. They acquire the land, map a building scheme without technical support, provide acquisition of construction material, agency labor (free or informally paid), and build their home. In Brazil mostly of construction labor lack professional training. Furthermore, innovative techniques faces difficulties to take place, as for instance double-glazed windows, insulation, and vapour barriers. Due to the low demand, these materials are imported, making its price high.

These issues combined – informal construction, lack of professional training and innovative techniques – may lead to this predominance of masonry wall with clay tile roof usage.

As observed, Brazil is a wide and heterogeneous country. Population is mostly concentrated in Southern regions, which have the higher average incomes; Northern regions are the less occupied and the poorest ones. This low occupation is mainly because of the amazon forest that comprises a major part of North region, which has the highest values of precipitation. Despite of the moisture disorders risk due to climate, houses use almost the same construction techniques, the innovative ones faces difficulties to take place and labor lack professional training.

### **3. Standards and laws – societal demands governing moisture safe construction**

Considering that the vast amount of the single-story houses are informally built, means that they do not attend to Brazilian laws and standards requirements. The standards presented in this item may refer to measures directly linked to avoidance of moisture/leaking issues or to thermal properties of materials and design requirements that may affect the occurrence of moisture disorders. The presentation is according to the building lifecycle phases: design, construction, and operation. The societal demands governing moisture safe construction assessed are:



- NBR 15575 – Residential buildings – performance. The standard provides responsibilities for each agent of the chain of relationships of construction industry and it is applicable only to new buildings, not comprising retrofitting. As part of the standard the building must have a Manual of Usage, Operation and Maintenance, providing guidelines related to the operation and maintenance of the building and its equipment, in order to increase its lifecycle (ABNT, 2013)
- NBR 15220 – Thermal performance of buildings. This standard classifies the country into 8 bioclimatic zones with similar climate characteristics and formulate for each zone a set of recommendations and technical specifications in order to optimize the thermal performance of buildings (ABNT, 2005)
- RTQ-R – Labelling for energy efficiency of residential buildings. The purpose of this regulation is to classify the level of energy-efficiency of residential buildings, being the rating from A (more efficient) to E (less efficient). It is voluntary and can be applied to new and existing buildings (INMETRO, 2012)
- Local laws related to building design. In Brazil, each municipality has its own legislation related to building construction that must fulfil to federal and state laws. Local law generally defines Brazilian standards (NBR) to which design project must be accomplished.

### 3.1 Design Phase

The majority of standards requirements focus on the design phase. Regarding moisture safety, NBR 15575 is the most relevant standard once it refers specifically to floor, wall, and roof systems, that in turn refer to other specific NBR standards, as presented below.

For floor systems, the main recommendation is in order to avoid rising damp. Floor systems when waterproofed must satisfy the standard NBR 9575 – Waterproofing selection and project (ABNT, 2010). Its scope establishes the requirements and recommendations related to selection criteria of materials and to waterproofing project, to attend the minimum requirements of building protection against fluid crossing, so as the requirements for healthiness, safety, and comfort of the user, to ensure the water tightness of constructive elements.

In relation to driving rain, the wall system design must indicate constructive details of interfaces and component joints to ease water drain and avoid water infiltration, considering the exposure conditions of the building during its lifecycle. Protection around the building to avoid water accumulation in the building basis should also be considered.

The roof system must avoid rainwater, incidence of moisture, and microorganism proliferation. Waterproofing systems must be executed in accordance with the standard NBR 9575 (ABNT, 2010). It also must be able to dry the maximum precipitation value for the region in which the building is located to avoid water pools or overflow, by attending the national standard for sizing rainwater systems of buildings NBR 10844 (ABNT, 1989). The project must predict constructive details to ensure the non-occurrence of moisture and its consequences in the liveable environment for at least 5 years. The standard also provides a guide for development of designing, sizing, detailing, executing and maintaining for building sanitary installations.

Brazilian Standard NBR 15220 (ABNT, 2005) presents the Brazilian Bioclimatic Zones as previously shown in Figure 2. For each bioclimatic zone, the standard provides a bioclimatic chart in which data of temperature, relative and absolute air humidity are plotted, indicating the most appropriate construction guidelines such as ventilation openings area (defined as a function of the percentage of floor area) and thermal properties for building envelope. Figure 12 presents a model of the chart.

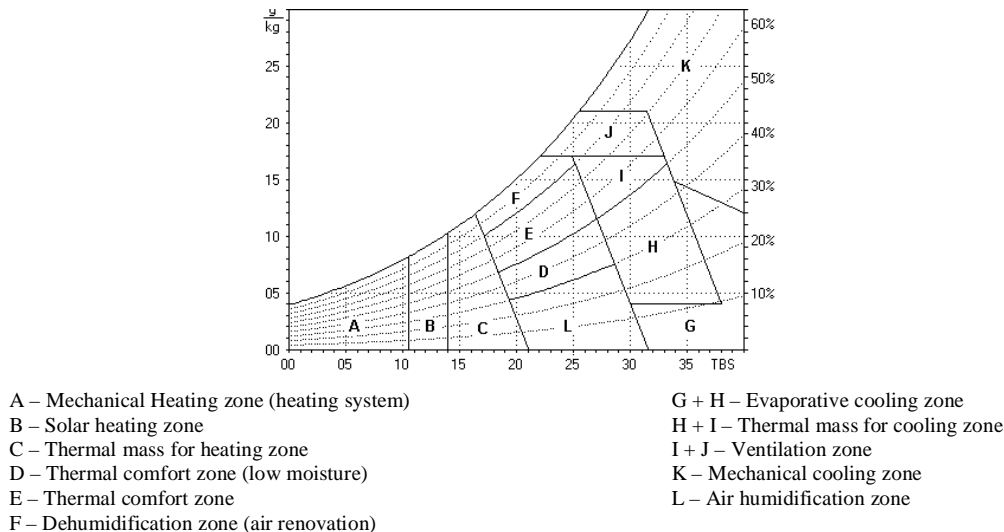


Figure 12 - Bioclimatic Chart

Source: ABNT (2005)

However, the guidelines are considerable generic, *e.g.* do not consider the orientation of openings, use thermal-physical properties not validated by measurement and only for a reduced number of construction types, and disregard the building geometry. Computer simulation is not required and there is a lack of climatic database. There are few engineering consultants to do simulations and their prices are extremely high.

In the RTQ-R, there is no directly moisture related evaluation item, but requirements related to ventilation and evaluation of the envelope. In order to achieve level A or B, bioclimatic zones 2 to 8 require cross ventilation rates that must provide airflow between openings located in at least two different façades and in two different orientations. The requirements for envelope evaluation are in relation to geometry, thermal properties, use of insulation in cold zones, size and solar orientation of façades and openings.

Table 3 presents a comparison between the ventilation openings sizing and thermal transmittance requirements of the standards presented. It can be noticed that there is no compliance for some requirements.

Table 3 – Ventilation openings and thermal transmittance requirements

Requirement	Standard	Bioclimatic Zone							
		Z1	Z2	Z3	Z4	Z5	Z6	Z7	Z8
Ventilation openings (V) [% of floor area]	NBR 15220	$15 < V < 25$	$15 < V < 25$	$15 < V < 26$	$15 < V < 27$	$15 < V < 28$	$15 < V < 29$	$10 < V < 15$	$40 < V$
	RTQ	$V \geq 8$	$V \geq 8$	$V \geq 8$	$V \geq 8$	$V \geq 8$	$V \geq 8$	$V \geq 5$	$V \geq 10$
Thermal transmittance (U) [W/m <sup>2</sup> k]	w NBR 15220	$U \leq 3.00$	$U \leq 3.00$	$U \leq 3.60$	$U \leq 2.20$	$U \leq 3.60$	$U \leq 2.20$	$U \leq 2.20$	$U \leq 3.60$
	a RTQ								
	l NBR 15575	$U \leq 2.50$	$U \leq 2.50$	$U \leq 3.70$	$U \leq 3.70$	$U \leq 3.70$	$U \leq 3.70$	$U \leq 3.70$	$U \leq 3.70$
	r NBR 15220	$U \leq 2.00$	$U \leq 2.00$	$U \leq 2.00$	$U \leq 2.00$	$U \leq 2.00$	$U \leq 2.00$	$U \leq 2.00$	$U \leq 2.30$
	o RTQ								
	f NBR 15575	$U \leq 2.30$	$U \leq 2.30$	$U \leq 2.30$	$U \leq 2.30$	$U \leq 2.30$	$U \leq 2.30$	$U \leq 2.30$	$U \leq 2.30$

Source: adapted from ABNT (2005), INMETRO (2012), ABNT (2013)

Some additional laws can be imposed on the design phase of the building. For instance, for the city of Curitiba (Z1), there is no law directly related to moisture avoidance, but conditions that the building must meet such as minimum requirements to floor area, natural lighting, natural ventilation area and source, and type of internal finishing. The sizing of openings is a proportion of the floor area.

For São Paulo (Z3), the building law requires waterproofing for every slab with ground contact and refers to related standards NBR 9575 (design) and NBR 9574 (ABNT, 2008) (execution). Walls with ground contact and/or south oriented also require waterproofing. Sizing of lighting and ventilation openings is according to the use and the geometry of the building.

The building law of Rio de Janeiro (Z8) have many requirements related to light well and airshaft, considering is an old city with narrow building lots and many existing semi-detached buildings, this is a main concern. However, it does not consider the high rates of air conditioning use in the city, one of the biggest of the country. Sizing of openings have a similar approach to Curitiba, a proportion of the floor area of the compartment. There is no specific moisture related demand, just general recommendations in order to ensure the sealing of the building.

In order to obtain a building permit, the city hall competent body must inspect the building design. However, the attendance of the standards required by the local law is normally a responsibility of the architect/engineer, but there is no organization to proper control the attendance of these standards.

### 3.2 Construction Phase

For construction phase, only NBR 15575 presents related requirements for wall, floor, roof, and sanitary systems, which in turn cite other specific NBR standards. Floor systems when waterproofed must satisfy the standard NBR 9574 – Execution of waterproofing – Procedure (ABNT, 2008). For wet areas, the floor must not permit the occurrence of moisture. The bottom surface and the joints with walls and adjacent floors that delimit the floor must remain dry when submitted to a water blade of 10mm for 72h.

For envelope sealing considering driving rain there are two types of tests. The specimen must accurately represent the design with its construction characteristics of vertical sealing and its components joints. The first test option consists on submitting during a predicted amount of time the outer surface of a specimen to a water flow, creating a homogeneous film with a simultaneous application of a pneumatic pressure. The standard presents the test conditions of water flow and static pressure according to the wind velocity regions of the country. The second test option is according to the standard NBR 10821 (ABNT, 2000) that provides requirements for water tightness of windows and the elements in which they are fixed. For sealing of surfaces subjected to direct water incidence, the test consists in submitting part of a wall to water presence with constant pressure and the amount of water infiltration must not exceed 3cm<sup>3</sup> for a 24h period.

For roof systems the evaluation through laboratory test consists in submitting a specimen to a water flow under a condition of static pressure difference, being accepted the occurrence of stains if it does not exceed 35% of the area. Barriers for solar protection must proceed to emissivity limit of  $\varepsilon=0.2$ ; thermal insulation must proceed to at least 90% of the thermal resistance informed by the manufacturer; and for vapour must proceed to vapour permeability equal or lower than 11.4x10<sup>-8</sup> g/Pa.s.m<sup>2</sup>. Waterproof slabs must be executed according to the NBR 9575 (ABNT, 2010) and resist the water line test for at least 72 hours.

The criteria for the sanitary installations is that pipe system must not present leakage when submitted, for one hour, to hydrostatic pressure of 1.5 times of the value predicted in project. For sewage and rainwater, pipe system must no present leakage when submitted to the static pressure of 60 kPa during 15 minutes.

However, these tests need properly equipment and laboratory to be conducted, that are not always accessible. The country also lack training course for construction workers, which is not required by most companies. In addition, there is no engineering consultant specialized on the building energy efficiency that could assist the building workers. For instance, there is not consultants to perform airtightness tests in Brazil.

### **3.3 Operation Phase**

For the operation phase, NBR 15575 recommends that sealing surfaces in contact with wettable areas, which are those subjected to splashing water (bathrooms, kitchens, laundries, sidewalks), it must not have perceptible presence of moisture in the adjacent rooms, respecting the occupation and maintenance conditions predicted in project.

Regarding indoor microorganism's proliferation, it must be ensured healthiness considering the moisture and temperature inside the building herewith the construction methods used. In relation to the presence of pollutants in the interior atmosphere, the standard establishes that equipment and systems must not release products such as carbon dioxide and aerosols that lead to a worsening in the interior air quality.

For the operation phase, the accordance verification is restricted to formal construction, for whose the companies must ensure the minimum period of 5 years of guarantee.

#### **4. Research on moisture carried out in Brazil**

The birth of post-graduate programs in Brazilian universities in the seventies contributed to promote the formation of building research groups in the country working on software application and theoretical aspects of building physics.

In the early eighties, a group of researchers at the Department of Mechanical Engineering of Federal University of Santa Catarina (UFSC), concerned with the petroleum crisis, begun a series of studies on how the energy consumption in the built environment could be reduced. The Passive Thermal Systems Laboratory (SITERPA), as the group was called at that time, developed some moisture related research regarding the heat and mass transfer phenomenon in porous building materials (Souza and Philippi, 1985, Silveira Neto and Philippi, 1986), convection (Biage and Philippi, 1985), and building simulation (Philippi, 1985, Souza and Philippi, 1986, Abreu, 1986, Cunha Neto et al., 1988). By that time, the severe lack of data made them turn their attention to the measurement and prediction of hygrothermal properties of porous building materials. Some research projects were dedicated to develop instruments, procedures, and equipment to thermal property measurements (Guths et al., 1990, Fernandes et al., 1990b, Fernandes et al., 1990a). At the same time, the study of heat and mass transport processes, which take place in the microstructure of porous building materials, have been undertaken to predict thermal properties required for thermal simulation, using microstructural description of the porous medium (Perin et al., 1987, Quadri, 1988, Quadri and Philippi, 1988, Quadri et al., 1988, Fernandes et al., 1989, Fernandes et al., 1990b, Fernandes et al., 1990a, Guths, 1990, Fernandes, 1990).

In the nineties, with the continuous growth of the research domain, the group has been divided into three new laboratories, each one attached to a different University department but still working in cooperation: LMPT- Laboratory of Porous Media and Thermophysical Properties at Mechanical Engineering department (LMPT, 2016), LabEEE - Building Energy Efficiency Laboratory (LabEEE, 2016) at the Civil Engineering department, and LabCon – Environmental Comfort Laboratory (LabCon, 2016) at the Architecture department. LMPT concentrated its research efforts in transport properties of porous materials including concrete, mortar and wood (Souza et al., 1991, Philippi, 1991, Philippi, 1993). In those works, numerical and experimental approach have been used (Cunha Neto and Daian, 1993, Bueno et al., 1994, Guimarães et al., 1995, Philippi and Souza, 1995, Guimarães et al., 1997, Mendes, 1997, Mendes et al., 1999, Mendes et al., 2000). Mendes (1997) in collaboration between UFSC/LMPT and the Simulation Research Group at the Lawrence Berkeley National Laboratory (LBNL), in California – USA, developed mathematical models for estimating material properties and predicting heat and moisture transfer through porous building elements and elaborated the DOS version of the UMIDUS program.

In 1998, a new research space called Thermal Systems Laboratory (LST, 2016) was established at the Pontifical Catholic University of Parana (PUCPR) and a Windows version of the Brazilian

software UMIDUS (Mendes et al., 1999) was developed to predict heat and moisture transfer through porous building elements with cooperation with UFSC/LAbEEE-LMPT. Also In collaboration with UFSC/LMPT, a new method to solve highly coupled equations of heat and moisture transfer through porous building materials have been developed (Mendes et al., 2001b, Mendes et al., 2003, Mendes and Philippi, 2004, Rode et al., 2004, Mendes and Philippi, 2005), allowing to perform the whole building hygrothermal prediction

Also in late nineties, an OOP building simulation program called DOMUS (Mendes et al., 2001a, Mendes et al., 2008) started to be developed at LST, integrating the UMIDUS capabilities and allowing DOMUS to perform the whole-building hygrothermal simulation. In 2003, (Santos and Mendes, 2003, dos Santos and Mendes, 2004) presented the software Solum to predict 3-D profiles of temperature and moisture content in soils under buildings and some research concerning moisture in soils was carried out numerically (dos Santos and Mendes, 2006, Dos Santos and Mendes, 2005) and experimentally (Olukayode and Nathan, 2007, Akinyemi et al., 2007, Mendes et al., 2012). Moisture rising damp related problems are commonly found in Brazilian constructions.

Grigoletti and Sattler (2007) developed a method to evaluate the hygrothermal performance of low cost single-story houses in the city of Porto Alegre, South of Brazil. It is mentioned the fact that the existing standards of Brazil do not consider items such as solar orientation of the openings, geometry of the building, superficial temperature of the surfaces to avoid water condensation, ventilation for indoor air quality nor heterogeneity of the superficial temperatures (that may lead to thermal bridges).

Dos Santos and Mendes (2009a) presented a new model to compute temperature, vapor pressure and air pressure profiles in porous elements. The same model was used to compute 2-D simulation in hollowed porous elements and thermal bridges (dos Santos and Mendes, 2014, Coelho et al., 2009, dos Santos et al., 2009, dos Santos and Mendes, 2009b) and roofs (dos Santos and Mendes, 2013). As insulations materials are not really used in the country and we see a large potential to their use underneath the roof, we believe a research focus and elaboration of guidelines are needed to reduce moisture problems in roof systems.

LST has also performed simulations using the moisture model of EnergyPlus and carried out a study on sensitivity and uncertainty analysis applied to combined heat and moisture models (Goffart et al., 2015). More recently, some 2-D and 3-D research on moisture models was integrated to the whole-building simulation code Domus and has been presented in Berger et al. (2016). Other two on-going PhD thesis are very focused on this topic, creating a plug-in in a commercial software to be fully integrated into Domus.

Related to moisture buffering effect, an 8m<sup>3</sup> experimental test cell was created at PUCPR/LST in order to evaluate the effect and also to validate heat and moisture transfer models (Meissner et al., 2010). In addition, an on-going thesis is carried out in collaboration with University of Savoy on the development of new materials with a high moisture buffer capacity.

As examples of moisture disorder in buildings with case study approach, Sobrinho (2008) analysed the presence of fungi in the mortar of social houses in the countryside of São Paulo, Southeast of Brazil. According to this study, one of the main issues that occur in social houses is rising damp in the mortar due to lack of waterproofing between the floor slab and the soil. Oliveira (2013) studied the main causes that lead to construction disorders in residential buildings. In the construction company, the disorders occurred mostly in the execution (52%) and design (18%) stages. Hydraulic installations, facades and waterproofing sum 49.3% of the requests of technical assistance in the post-occupation period.

The influence of driving rain and of the architectural elements in front of deterioration of the façades were assessed for multi-story residential buildings in the city of Goiania, located in the Central West of Brazil (Júnior and Carasek, 2014). The study verified that moisture from rain deteriorate facades mostly on platbands, windowsill, and drip pans. However, stains occur not only due to facades elements, but also by condensation in masonries, mainly in the South façade, what can lead to microorganism growth.

Therefore, some research work in Brazil has been carried out about moisture in constructions since 80's, but still strictly academic or in a case study approach such as exemplified above.

As building design in Brazil has been pushed towards energy efficiency due to the recent establishment of regulations and standards, attracting professionals, consultants and the building sector to the theme, we believe a similar effect might happen with moisture, especially with the possibility of decreasing the overall heat transfer coefficient of roofing systems.

## **5. Discussion**

Despite the fact that Brazil is a large country with very different climates, income inequalities and cultural differences, the majority of the houses use quite the same construction techniques. The standards and laws have different requirements and most of the time are not respected somehow due to the lack of control. Some of them do not take into account the climate as it was shown in section 3, although it represents an important source of moisture with potential risk of mould growth.

None that handles with thermal performance (NBR 15575, NBR 15220, RTQ-R) considers moisture as an evaluation requirement, regardless of its importance. As shown by Mendes et al. (2003), the effects of moisture on conduction loads in walls may lead to oversizing HVAC equipment (especially in dry climates) and to underestimating energy consumption (especially in humid climates), indicating the importance of considering both moisture and weather when dealing with building thermal performance.

Even for constructions with building permits, standards requirements are not always met, as it depends on local laws and supervision. Standards tests require laboratory and equipment that are not always accessible, as they are most of the times located into Universities, which turn their meet more difficult.

There is a cycle between construction methods and standards: the same construction techniques are widely used for years and the standards mainly refer to these type of techniques. Government do not encourage the evolution of new techniques due to the absence of standard new materials. Bureaucracy also plays a role on this difficulty in changing construction methods – if it is not standardized it cannot be used, especially for large buildings that depend on external financing (in Brazil the major funding entity for residential construction is a federal bank).

Mjörnell *et al.* (2011) presented a validated method associated with some tools to be used in order to manage moisture safety in the building process that includes routines, templates and checklists for all parties concerned in all stages in the building process. However, these method and tools assume that there is a project management, with a design phase, a constructor and a building operator. Thus, it does not suit with Brazilian typical construction, as mentioned that over half of the single-story houses are informally built. Even constructions with building permit are not build with professional workers, as in Brazil construction labor it is not a regulated profession.

There are a few tools for moisture control in the building process. One important lacking task is to formulate this knowledge so that it can be applied in all stages and by everyone involved in the design, construction, and operation phases of a building lifecycle.

## **6. Conclusions**

Climatic conditions – high outdoor water vapour pressure, high precipitation rate, driving rain – and low construction quality – great amount of informally built houses, difficulty on attending standards requirements, standards failure on considering moisture and climate, lack of professional labor, cultural and income differences within the country – put the populous country in a position of high attention to the risks of moisture disorders. However, instead of being a recurrent issue in building pathology, moisture is commonly neglected by researchers and building owners in Brazil.

Probably due to cultural issues and to the great amount of informal construction, moisture disorders are currently faced as something unavoidable, particularly for condensation and mould growth that are not necessarily related to execution failure.

Although there is a significant research related to moisture around the world, it is mainly in cold climate countries, for whose moisture represent a major issue once it directly affects thermal performance, deterioration of building envelope and the already high energy consumption. Moisture research in Brazil started in the early eighties and it is still mainly concentrated in universities with very modest application with the building industry. Some difficulties are related to absence of legislation and lack of a database of hygrothermal properties. Nowadays, no laboratory is carrying on measurements to determine moisture related properties.

Nevertheless, the issues presented indicate there is a large potential for conducting research in Brazil on this topic. So far there is no study in the country that assesses the influence of moisture on building energy performance, material deterioration and pathology.



As it has been noticed, since the nineties there is in the country an expressive growth related to building energy efficiency, especially after the creation of standards NBR 15575 and regulations RTQ-C and RTQ-R. We also believe in a similar positive future for the development of moisture research and real application in the building sector in this beginning of the 21st century, especially with the trends of decreasing the overall heat transfer coefficient of roofing systems in residential and commercial buildings.

Suggestions for further work are the accurate assessment of potential risk for mould growth in the different bioclimatic zones (considering building construction), use of simulation to analyse the influence of moisture on energy efficiency considering the Brazilian building type construction, providing guidelines on how to propose robust retrofit in relation to moisture issues and database of building materials commonly used in the country.

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# ByggaF - A Method to Include Moisture Safety in the Construction Process

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## Abstract

ByggaF is a methodology for including moisture safety in the construction process that was developed and presented in 2007. ByggaF comprises methods to secure, document and communicate moisture safety throughout the construction process, from planning to management. The methods involve a standardized way of working designed to meet the demands of society and the client's requirements for moisture safety. On request from the Swedish construction sector, ByggaF has been transformed into an industry standard. Since then, ByggaF has been used in a number of Swedish construction projects. One reason for the broad implementation of ByggaF is that the Swedish environmental assessment tool Miljöbyggnad demand for using ByggaF in order to reach "silver level" or "gold level". Another reason is that more than 100 moisture experts have been trained to use ByggaF to assure a moisture safe building process. There has also been interest in using ByggaF expressed from other countries. The industry standard has been translated to English but it needs to be adjusted to country specific conditions, such as regulation and building practices in order to be applied in other countries. In Finland, the Swedish version of ByggaF has been adapted to Finnish regulations and used for including moisture safety in construction of a school at Bergö. There have also been attempts to adjust ByggaF to suit specific applications such as construction of prefabricated single family houses and renovation of multifamily houses.

**Keywords:** Moisture safety, moisture experts, industry standard, construction process

# 1. Introduction

Moisture damage affecting our buildings is a major problem and involves major costs for repair. Despite today's modern construction methods, the trend is not declining for this type of damage. Moisture damage may cause bad indoor environment, which in turn can have an adverse effect on human health. For home-owners, moisture problems often cause major unexpected expenses. The reasons for moisture damage arising in buildings are due to a number of different factors. This could be an unclear allocation of responsibilities, ambiguous requirements, scanty follow-up and monitoring, unrealistic time schedules, lack of communication between the stages, inadequate skills and insufficient procedures for assuring moisture safety. It could just as well be due to introduction of new types of structures, materials and components without a proper verification of moisture resistant properties. This may lead to degradation in the presence of moisture, with emissions, microbial growth and stability problems as a result. It is therefore extremely important to design moisture-proof structures composed of materials that can withstand the moisture loads that the structure is expected to be exposed to during its service life, and to ensure a suitable environment for the building both during the construction stage and the operational stage. Requirements for moisture safety may often conflict with other requirements such as accessibility, architectural and design requirements as well as energy requirements. These conflicts need to be addressed and resolved throughout the entire construction process.

In order to put more focus on the moisture issues and to work with a structured approach in the construction process, ByggaF – A methodology for including moisture safety in the construction process was developed and presented in 2007, ByggaF (2007) and Mjörnell et al (2012). The methodology was then introduced to the Swedish construction sector and is today widely used by building owners (here referred to as clients), designers and contractors. In 2013 ByggaF was made into an industry standard.

The purpose of ByggaF is to highlight moisture issues at an early stage in new construction, renovation and refurbishment projects and to document the activities and actions that are required and performed in a structured way to ensure a moisture-proof building. By early formulating and setting moisture requirements and requirements for the activities, these can be incorporated into the program documents, system documents, construction documents and control plans, etc. This means that the important choices of systems and designs as well as of materials and production methods that will impact the moisture safety of the building can be made from the beginning. There have though been doubts about what parts of the ByggaF methodology are compulsory and what parts are optional. Therefore, the methodology was developed into a Swedish industry standard for the construction sector in 2013, Mjörnell (2013). The aim with this paper is to disseminate awareness and knowledge about the Swedish industry standard ByggaF to make it available for other countries to apply in their quality management work. The aim is also to give a picture how ByggaF is used today in Sweden and partially in Finland as well where it was used for construction of Bergö school, and how ByggaF has been further developed and adapted to other uses such as prefabricated single-family houses and renovation, (Johansson and Bengtsson, 2015) and (Olsson and Tjäder, 2016).

## 2. The Method ByggaF

Industry standard ByggaF includes a method that secure, documents and communicates moisture safety throughout the construction process, from planning to operation of the building. The method involves a way of working designed to meet the demands of society and the client's requirements for moisture safety. The full industry standard written in Swedish is available at the website of Swedish moisture centre, [www.fuktcentrum.se](http://www.fuktcentrum.se), where there is also a direct translation of the standard into English. This paper only describes the outlines of the ByggaF method. For a detailed description we refer to the industry standard.

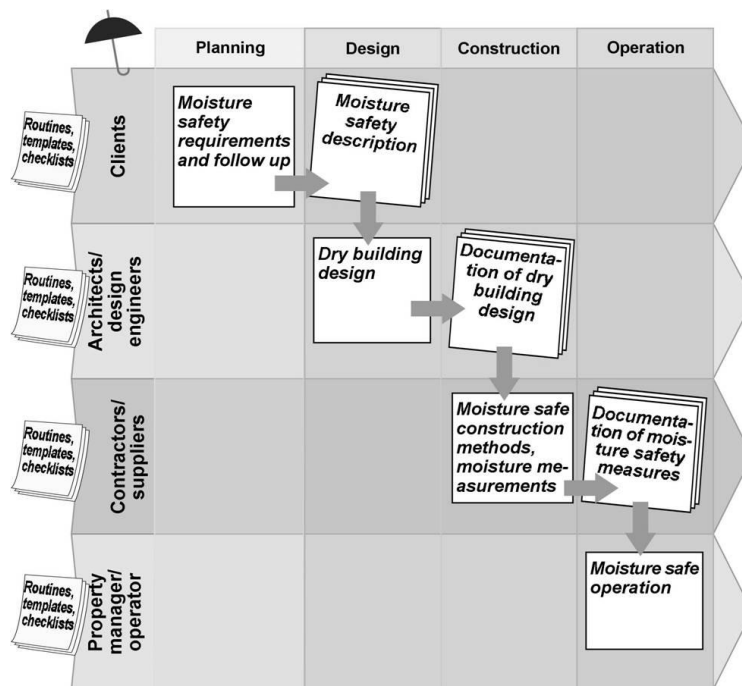


Figure 1 Overall picture of the ByggaF method.

The industry standard is designed to follow the stages in the construction process and covers the activities to be carried out at each stage. In line with how the Swedish building regulations are written, the industry standard has both “must-have requirements” that must be met and in addition, there is a guidance text that can clarify, explain or give examples of what the “must-have requirement” means. The guidance may also contain advice.

### 2.1 Who is responsible for what?

According to The Planning and Building Act, PBL, the client is the one who performs or fails to perform the planning, construction, alteration, renovation, demolition or excavation work. In order for the building to be planned and designed correctly, the client should engage the appropriate skills for the different work tasks. In many cases, the client hires a project manager as an extended arm in the construction process. However, the client is still responsible for compliance with the laws and regulations such as PBL and BBR. The client does not always



possess enough knowledge or time to pursue and monitor the moisture safety work in the project. It can be very helpful for the client to hire a person who is an expert in moisture safety, a moisture expert. The moisture expert can help the client to set requirements for moisture safety and to monitor compliance of the requirements. However, the practical moisture safety work is performed by all participants, planners, designers, contractors, suppliers and operators. The allocation of responsibility for different moisture safety activities at different stages may vary with different forms of construction contracts. Depending on the contract form, the responsibility boundaries are moved between systems planning, detailed planning and production. In the forms of contracts where the contractor also has the role of designer, the contractor must also take responsibility for what in this document are called designers' activities and responsibilities. In design and construct contracts, the responsibility for continually monitoring the moisture safety work lies with a coordinating moisture safety manager (MSM) for the production stage.

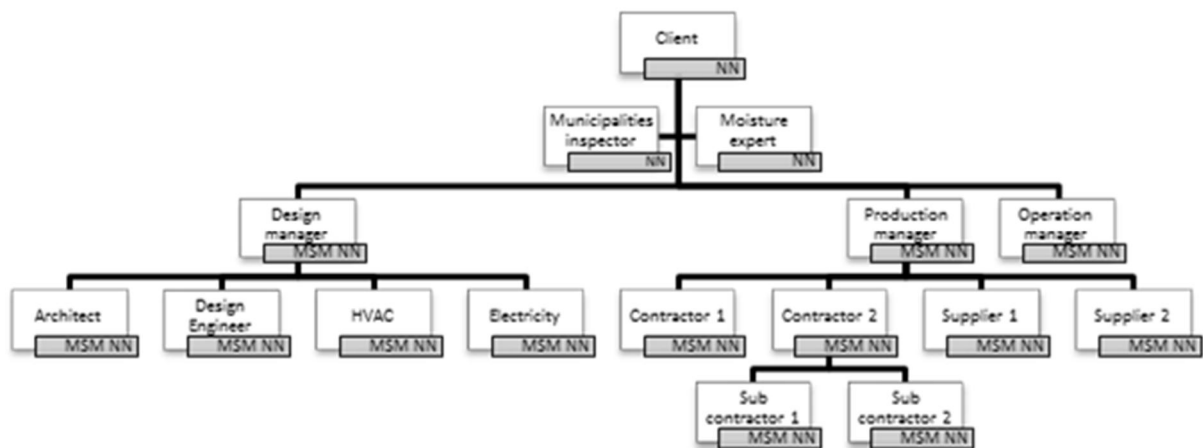


Figure 2 Responsibilities for the moisture safety work in the project organisation.

## 2.2 Moisture safety in the planning stage

The first thing the client should do is to appoint a moisture expert. Our experience is that involving a moisture expert following up the moisture safety work in the project is of crucial importance for the result. To start with the moisture expert will support the client making the early moisture risk analysis which he or she is responsible for. By making an early risk analyses before the mayor decisions about the buildings location, foundation practices, principles for handling rainwater, drainage systems, supporting framework, construction methods etc. are made, moisture critical constructions and designs could be avoided, which will save time and money in the long run. The moisture expert may also help the client to decide on the moisture safety requirements to be set in the project. It must be possible to verify and monitor the moisture safety requirements. The requirements must include both technical requirements and requirements for activities and skills.

## 2.3 Moisture safety in the design stage

Already in the procurement and contracting of planners and designers it is important to inform them about the moisture safety requirements and the methods that will be used to monitor

compliance of the requirements. Each participant involved in the design stage, designing materials, building elements or installations that affect the moisture safety of the building must follow the procedure for moisture safety design. To start with, all structures and materials sensitive to moisture and moisture critical work operations must be identified. The next step is to estimate the moisture condition that the various building elements and materials as well as combination of materials will be exposed to and describe how they vary in time. Then the estimated moisture conditions are to be compared with the permitted moisture conditions in order to evaluate the probability of damage to occur.

## **2.4 Moisture safety in the production stage**

Ahead of production, the moisture expert supported by project planners and designers must notify the main contractor of the result of the moisture safety planning and motivate their choice of construction and designs and can also answer questions regarding the drawings and technical descriptions. This is also an opportunity for feedback on the planning and design process.

Firstly, moisture-sensitive elements, structures and installations that are important in production are identified. Secondly, a moisture safety plan is prepared that describes the moisture safety measures to be undertaken in order to protect the building and construction materials from damaging moisture during production and must also include the control points identified during the planning stage. The moisture safety manager for production must ensure the implementation of the activities in the moisture safety plan as well as implementation and documentation the measurement and inspections according to the moisture safety plan. Moisture inspection rounds at the construction site are performed by the moisture safety manager and the moisture expert throughout the construction process.

In the end of the construction process, the moisture safety manager collects data for operation and maintenance instructions for moisture safety from subcontractors and suppliers as well as data from the moisture safety work carried out by subcontractors and suppliers, and submits this to the moisture expert, who in turn compiles the moisture safety documentation from planning and production and submits it to the developer.

## **2.5 Moisture safety in the operation stage**

In the commissioning stage when the building is handed over to the building owner, the developer's moisture expert and the moisture safety manager for production go through the moisture critical structures of the building and the measures to be carried out to ensure that moisture safety is maintained, with the responsible administrator and operations manager. During subsequent management of the building, the operation manager, on behalf of the building owner, is responsible for carrying out recurrent operational inspection rounds, in which moisture safety is one of many aspects to be considered.

### 3. Experiences from using ByggaF

In order to get an idea on how frequently ByggaF is used in the construction industry today and to get feedback on the field of application, usefulness and suggestion for improvements, 25 deep interviews were conducted. The interviewees were selected partly from the lists of moisture experts holding a diploma from Swedish moisture centre, partly from moisture experts who have been involved in projects that have received “gold level” in the Swedish environmental assessment tool Miljöbyggnad, a certification system for buildings, based on Swedish construction rules and regulations such as BBR, which implies working according to ByggaF.

The results from the interviews indicate that many of the users are concerned with the paper work originating from the requirement of documentation of requirements, moisture safety design and moisture safety activities during production. They ask for shorter documents summarizing the most important issues to be communicated. The documents aimed for the building owner are less frequently used and moisture experts are engaged at a later stage in the process. The interviewees are also concerned about insufficient knowledge and engagement on the part of the building owners. Another concern is the building owners unwillingness to spend money on moisture safety expertise in the beginning of the project when it would be easier to form the basis of a moisture safe design and construction, rather than to be involved later in the process to manage moisture safety issues when conditions for assuring moisture safe building are bad or even when things already have gone wrong. Critical decisions influencing the moisture safety of the building are taken early in the construction process. Another concern is that too much time is spent on meetings, rather than on constructive work.

Yet another concern is that architects and design engineers’ levels of ability vary when it comes to moisture safety design. There is also a lack of practice to document the moisture safety design and an uncertainty how to perform risk analyses. Today, risk analyses are done based on earlier experience from damages which is not sufficiently enough. In some cases the risk analyses has been disregarded. The competence among the contractors is also low and there is insufficient information and communication between employee and workers.

The moisture inspection round is an appreciated and frequently used activity and the template for documentation is widely used. However, some companies have slightly adapted the template in order to make it easier to include pictures taken during the rounds. There are also attempts to make a digital tool for the moisture inspection round. The application is however not yet launched on the market.

Many ask for a less comprehensive version of ByggaF and some companies have adjusted the documents, such as the moisture safety description, moisture design and risk evaluation, moisture safety plan and moisture round protocol, to make them easier and more suitable for their own work processes.

Among the things the interviewee asked for is a certificate affirming that the ByggaF has been used in the building process and an adjustment of ByggaF to small projects. They also stress on

the importance to bring up moisture issues and moisture risks early in the building process before the procurement documents are sent out.

## **4. Adjustment of ByggaF to other uses**

As a result of the relatively wide use of ByggaF, there have been inquiries to adjust ByggaF to specific construction processes such as construction of single family houses as well as renovation. Such attempts have been made by students in the form of two diploma works. The aim with the first study was to adapt ByggaF into a modified method ByggaF- PST applicable to the industrialized manufacturing process of single family houses with timber frame, in order to assure that it fulfills the moisture requirements specified in the buildings regulations. This work was done in collaboration with the housing industry.

The prefabricated manufacturing building process requires adjustments in ByggaF because the building process involves construction of modules and elements in a factory. For this reason ByggaF-PST includes a new stage; manufacturing of modules in factory. Another difference is that the client in most cases chooses a house from a catalogue. This means that the house already is more or less planned and designed when the client gets involved in the project. The house consists of prefabricated modules manufactured inside a factory, delivered to the building site where they are put together. For this reason there is an essential difference between the prefabricated and an ordinary building process. This affects the activities, stages, and parties involved in the presented method ByggaF-PST.

Since the client comes in late in the process, after the design is decided, and generally would not have the knowledge or the competence of setting requirements or following up moisture issues, the role as the moisture expert is delegated to the house supplier. The checklists for design as well as the risk evaluation are adapted to the most common design of prefabricated single family house modules. Another difference is that the production stage is divided into two; production of modules in factory and erection at the building site. (Johansson and Bengtsson 2015)

The aim of the second study was to adjust ByggaF to the renovation process. As a first stage interviews were conducted asking the users how ByggaF needs to be adjusted to better suit the renovation process. There was a concordance among the interviews that the most important document to further develop is the routine and checklist for inventory and investigation prior to renovation. There is also a need to adjust the procedure and template for moisture risk evaluation to suit constructions most critical in the process of renovation. The work is ongoing and not yet published. (Olsson and Tjäder, 2016)

## **5. Administration and training in ByggaF**

The industry standard ByggaF is administrated by the Swedish moisture centre. Every year Lund University together with SP Technical Research Institute of Sweden arrange training for moisture experts. It is a 10 days of lectures (compulsory), a number of assignments to work with at home between the training occasions and a written examination in the end. When all training

requirements are fulfilled the attendees get a diploma. Until now, approximately 220 persons have attended the training and 100 persons have got the diploma.

Every year, a regathering for all the attendees is arranged. The aim of this meeting is to exchange experience how ByggaF is used in the construction industry, feedback on specific drawbacks and suggestion for improvement and to inform each other of new types of moisture safety problems in general but also on new research and regulations concerning moisture issues to be better prepared for the commission as moisture experts.

Additionally, ByggaF is introduced to the students at Lund University as well as at Chalmers University.

## **6. Discussion**

The extensive use of ByggaF may partly be explained by an advice in the Swedish building regulation BBR but also due to the fact that ByggaF must be used in order to achieve gold or silver level in the Swedish environmental certification system Miljöbyggnad. However, we have very little knowledge to what extent the different parts of ByggaF is used since it is not required to report this in detail for achieving the certificate. The results from the interviews indicate that many of the users are concerned with the heavy paper work originating from the requirement of documentation of requirements, moisture safety design and moisture safety activities during production: It is however important to keep track of activities and decisions done and a comprehensive documentation is indispensable if a retrospect is needed. The ByggaF users ask for shorter documents summarizing the most important issues to be communicated. This is something that will be considered in the further development of ByggaF. Even though the results from the interview study point out a demand for higher competence levels among the actors, the situation is much better than a couple of years ago but of course the competence levels among all actors need to be increased. Training courses suited for different actors such as clients, moisture experts, contractors and design engineers have been developed and arranged by the Swedish moisture centre at least once a year.

## **7. Conclusions**

The industry standard ByggaF includes a method that guarantees, documents and communicates moisture safety throughout the construction process, from planning to management. The industry standard involves a standardized way of working designed to meet the demands of society and the developer's requirements for moisture safety. The purpose of the industry standard ByggaF is to highlight moisture issues at an early stage in new construction, renovation and refurbishment projects and to document the activities and actions that are required and performed in a structured way to ensure a moisture-proof building. By formulating and setting moisture requirements and requirements for the activities, these can be incorporated into the program documents, system documents, construction documents and control plans, etc. This means that the important systems and material selection and production methods that will impact the moisture safety of the building can be made from the beginning. The aim is to make it clear and easy for the building owner to

work according to the methodology and support him or her in the formulation and following up of moisture requirements during the different phases in the construction process. The industry standard has been developed in collaboration between researchers, building owners, contractors, design engineers and authorities. It is an open access standard available to download at [www.fuktcentrum.se](http://www.fuktcentrum.se). The English version makes it possible to use the industry standard not only in Sweden but also in other countries and in international construction projects. The requirement part of the industry standard must however be adapted to national conditions and regulations.

An interview study was conducted to get knowledge about to what extent ByggaF is used by the Swedish construction industry today and what the users views and experience from using ByggaF as well as suggestions for further development and adjustment. The conclusion is that parts of ByggaF are widely used but the users express concerns about the low level of competence in moisture issues among both designers and contractors. There are also concerns about the heavy paperwork and a wish to make that less extensive.

Until now there have been two attempts to further develop and adjust ByggaF to suit specific needs such as the construction of prefabricated single family houses and renovation of multifamily houses have been conducted in the form of diploma works.

Swedish moisture centre is responsible for administration and training in ByggaF. Up to now, approximately 220 persons have attended training for moisture experts and a little more than 100 persons have received a diploma.

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# Moisture Management in the Building Construction Process in Japan

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## Abstract

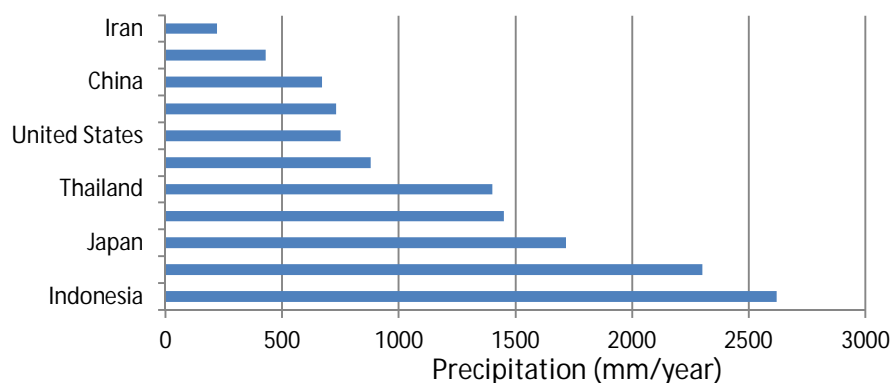
In Japanese buildings, moisture-related problems such as water leakage and condensation are common. Although the Japanese have extensive experience with various countermeasures, numerous problems need to be solved to guarantee a durable and energy-saving building without moisture problems. For this purpose, the Building Code for Promoting Qualified Residential Building (hereafter referred to as “Hinkakuho”) was enacted in 1999. The purpose, structure, technical standard, evaluation method, and guarantee system of this building code are briefly explained in this paper. In addition, recent research results related to vented wall cavities, attic ventilation, and condensation in spandrels of office buildings are explained.

**Keywords:** monsoon climate, Building Code for Promoting Qualified Residential Building (Hinkakuho), vented wall cavity, attic ventilation, condensation in spandrels.

## 1. Moisture Management Issues in Japan

### 1.1 Weather conditions in Japan

**(1) Large amount of precipitation** Because Japan is located in the boundary region of the monsoon climate and is surrounded by water, it receives a large volume of precipitation. The annual precipitation in Japan is approximately twice the world average (Fig. 1), which is one of the main reasons for the common occurrence of moisture-related issues.



*Fig. 1 World average of annual precipitation.*



- a) **Various moisture-related problems** Because the buildings in Japan are subjected to rain and snow throughout the year, suitable flashing such as roof waterproofing structures, eaves (including window eaves), rain gutters, sliding shutters, raised floors, adequate building ventilation, and crawl space are incorporated into a building structure. Nevertheless, numerous problems remain to be solved. A few of those are mentioned below.
- Deterioration of roof materials due to rain or snow: decay of wood, frost damage on roof tiles.
  - High humidity, decay of wooden elements, condensation during summer due to ventilation, and termite breeding in crawl space because of high groundwater level and soil water content.
  - High indoor humidity.
- b) **A large number of wooden buildings** The number of wooden buildings and amount of wood used per person in Japan are high. Wooden buildings in Japan have not been constructed air-tight, which might be a result of prioritizing comfort during hot and humid summers over comfort during cold winters.

## **(2) Four seasons and large regional differences**

Because Japan is an archipelago extending toward north and south, where its east and west sides face the Pacific Ocean and the continent of Asia across the Sea of Japan, respectively, local differences in the climate are rather large. Although the Japanese climate is regarded as mild, the contrast of hot, humid summers and cold, dry winters is clear and the differences between the four seasons is substantial. These seasonal and local differences cause different kinds of moisture problems.

### **1.2 Indoor conditions and lifestyle**

Because open-type heating devices such as oil or gas combustors were previously used extensively in Japan, moisture problems such as condensation, mold growth, and decay of wooden building elements are quite common. By contrast, along with the proliferation of heating devices that do not operate on combustion, such as heatpump and insulated buildings, dry indoor climates and shrinkage of flooring and condensation due to the use of a humidifier have appeared as new moisture-related issues. Local heating and cooling is quite common even now, and it causes temperature and humidity differences in a building, followed by condensation or mold growth. In addition, wooden buildings with numerous cracks are likely to be damaged by interstitial condensation due to air leakage or vapor diffusion.

## **2. Building standards and norms in Japan for moisture-safe construction**

### **2.1 Quality assurance systems in Japan: residential buildings**

#### **(1) Building Code for Promoting Qualified Residential Building (“Hinkakuho”)**

Most of the building standards and norms related to moisture-safe construction in Japan are specified in the “Building Code for Promoting Qualified Residential Building (1999)” published by the Ministry of Land, Infrastructure, and Transport.

[http://www.mlit.go.jp/jutakukentiku/house/jutakukentiku\\_house\\_tk4\\_000016.html](http://www.mlit.go.jp/jutakukentiku/house/jutakukentiku_house_tk4_000016.html)

This code was renewed 2009. Afterwards, the “Housing Performance Display System (HPDS)” was reviewed, and the “Japan Housing Performance Display Standard (JHPDS),” the “Evaluation Method Standard (EMS),” etc. were revised and promulgated February, 2014. Since then, the renewal of the Building Code (June, 2014), EMS, etc. were reviewed and promulgated

2015. HPDS was then reviewed again, and the JHPDS, EMS, etc. were revised and promulgated January, 2016, and were put into effect April, 2016.

## **(2) Background and objective of Hinkakuho**

The following problems are serious considerations for a person intending to acquire a house:

- ☐ Because no common rule exists for displaying housing performance, a suitable comparison is difficult.
- ☐ The method of evaluating housing performance is not reliable.
- ☐ No professional management system exists for dealing with troubles regarding housing performance; consequently, a large amount of labor is required for solving problems.
- ☐ When acquiring a newly built house, the warranty period of the contract is usually one or two years.

By contrast, the following problems are serious considerations for housing suppliers:

- ☐ Because no common rule exists for displaying housing performance, the incentive for competing housing performance is weak.
- ☐ Educating the consumer such that they understand the housing performance is not easy.
- ☐ A large amount of labor is required for handling complaints regarding housing performance.
- ☐ When acquiring a newly built house, a warranty period longer than 10 years is impossible.

From the standpoint that a new framework guaranteeing housing performance from production to after-sales service stages is essential to solve these problems, this new code, Hinkakuho, was established with the following objectives:

- ☐ To promote guaranteeing of housing performance;
- ☐ To protect the purchaser's interests; and
- ☐ To provide quick and fair solutions regarding housing problems.

## **(3) Framework of Hinkakuho**

Given such background and objectives, the framework of Hinkakuho is outlined as follows.

- ☐ Establishment of housing performance display system
  - By a common rule (“Display Standard” or “EMS”) that guarantees the fair display of housing performance (structural strength, acoustic insulation, and energy conservation), the purchasers can compare the housing performance of different houses.
  - A fair evaluation regarding housing performance by a trusted third party can guarantee reliability of the evaluation.
  - The displayed performance can be achieved on the basis of the principle that the housing performance stated in an evaluation document can be a contract.
- ② Development of management system dealing with housing performance problems
- ③ Exception of defect liability
  - In the contract when buying a newly built house, a warranty period of 10 years is required regarding the basic structural components.
  - In the contract when buying a newly built house, a warranty period up to 20 years could be possible, including parts other than the basic structural parts.

Notably, whether the Housing Performance Display System is used or not can be decided by a housing supplier, a person intending to acquire a house, or a dealer of existing houses.

#### (4) Japan Housing Performance Display Standard (JHPDS)

The JHPDS is the standard specifying items to be displayed and conditions for display regarding housing performance (structural safety, indoor air environment, care for the elderly, etc.). Fig. 2 shows an image of a housing performance display. It includes 10 fields covering 32 items for a newly built house, where two fields, ③ reduction of degradation and ⑤ thermal environment and energy consumption, are related to moisture management.

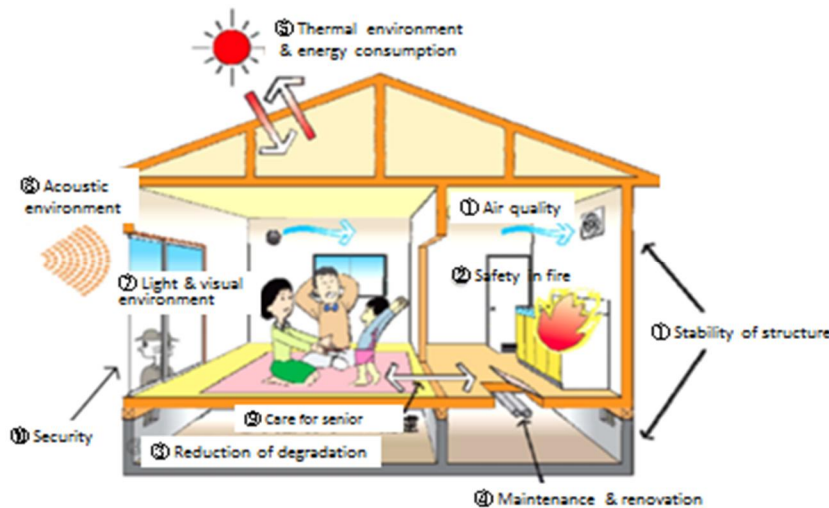


Fig. 2 Image of a housing performance display.

#### (5) Evaluation Method Standard (EMS)

This standard specifies an evaluating method for design documents and inspection methods regarding housing performance required by the Japan Housing Performance Display Standard (JHPDS). Existing houses were added as subjects in August, 2002.

#### (6) Evaluation of housing performance by registered institutions

#### (7) Management system dealing with problems regarding housing performance

#### (8) Exception to warranty

### 2.2 Evaluation Method Standard (EMS)

(<http://www.mlit.go.jp/common/001119167.pdf>)

Moisture-related issues are specified in two chapters (fields), “③ reduction of degradation,” (hereafter “3-Degradation”) and “⑤ thermal environment and energy consumption” (hereafter “5-Energy”). In the following sections, more details will be given. In this standard, “degradation” refers to the following:

- Wooden house: degradation of wood by decay and termites
- Steel-framed house: defects in cross sections of steel members due to rusting
- Reinforced concrete house: rusting of reinforcing bars due to neutralization of concrete and deterioration of concrete caused by freezing and thawing

In the following sections, only the contents related to the third-level measures will be described. Here, “third level” refers to the measures required to prevent deterioration within 3 generations, where one generation corresponds to approximately 25 to 30 years.

- (1) **External wall and roof** In 3-Degradation, only the treatment of termites is described. In 5-Energy, the following measures are specified for preventing condensation:

- When a fibrous insulation material such as glass-wool or cellulose fiber, or a plastic insulation material with small water vapor resistance is used, a vapor barrier must be installed to the building element connected to the outside (p. 98).
  - Nevertheless, a vapor barrier is not required if the sum of vapor resistances from the outer side of the insulation to the inside air, divided by the sum of vapor resistances from the outer side of the insulation to the outside air, is larger than the specified value (p. 99).
  - If the roof or external wall is insulated, installation of a vented air layer or any other measure effective for ventilation must be taken to the outer side of the insulation (p. 99).
- (2) **Attic space** Necessary number of ventilating openings and area are specified in 3-Degradation (p. 67) as follows:
- Behind the eaves, ventilating openings more than two must be installed at the positions effective for ventilation, and furthermore the effective opening area must be more than  $1/250^{\text{th}}$  of the ceiling area.
  - To the external walls of attic space, ventilating openings more than two must be installed at the positions effective for ventilation; furthermore, the effective opening area must be more than  $1/300^{\text{th}}$  of the ceiling area.
- (3) **Crawl space** The following are specified in 3-Degradation (pp. 66–67):
- The ground surface must be covered by reinforced concrete thicker than 60 mm, a vapor barrier film thicker than 0.1 mm, or another material with equivalent vapor resistance.
  - At external walls of the crawl space, ventilation openings must be installed with an effective area greater than  $300 \text{ cm}^2$  every 4 m of wall length.
  - However, this is exemplified in the case of thermal insulation foundation if the ground surface is covered by reinforced concrete thicker than 100 mm, a vapor barrier film thicker than 0.1 mm, or another material with equivalent vapor resistance and if the thermal resistance of the foundation is appropriate.
- (4) **Bathroom and dressing room** 3-Degradation (pp. 65–66) requires that frameworks of walls and floor of bathroom and dressing rooms and the ceilings of bathrooms must be finished with effective water proofing and that the bathroom be composed of a bath unit specified by JIS.
- (5) **Living space** There is no regulation.

## 2.3 Moisture related regulations to non-residential buildings

(1) **Indoor humidity** “The management standard of environmental sanitation for buildings”<sup>\*1</sup> in “Law for Maintenance of Sanitation in Buildings”<sup>\*2</sup> specifies that the relative humidity in living spaces should be maintained between 40 and 70% in air-conditioned buildings.

<sup>\*1</sup><http://www.mhlw.go.jp/bunya/kenkou/seikatsu-eisei10/>

<sup>\*2</sup>[http://www.mhlw.go.jp/stf/seisakunitsuite/bunya/kenkou/seikatsu-eisei09/index\\_1.html](http://www.mhlw.go.jp/stf/seisakunitsuite/bunya/kenkou/seikatsu-eisei09/index_1.html)

(2) **Humidity in schools** Regarding schools, “Standards of environmental sanitation at schools”<sup>\*3</sup> specifies that relative humidity between 30% and 80% is desirable.

<sup>\*3</sup>[http://www.mext.go.jp/component/a\\_menu/education/detail/\\_\\_\\_icsFiles/afieldfile/2010/08/06/1222311\\_001.pdf](http://www.mext.go.jp/component/a_menu/education/detail/___icsFiles/afieldfile/2010/08/06/1222311_001.pdf)

(3) **Regulation on moisture management** There is no regulation on humidity regarding non-residential buildings, although thermal insulation is required from an energy-saving viewpoint as PAL<sup>\*4</sup> (Perimeter Annual Load).

<sup>\*4</sup><http://www.kenken.go.jp/becc/>

### 3. Quality assurance systems in Japan

#### 3.1 System guaranteeing housing performance satisfying standards

A system guaranteeing housing performance satisfying standards is composed of the following items, as specified by Hinkakuho:

- Establishment of trusted third parties who give fair evaluations regarding housing performance and guarantee of reliability of the evaluation.

The housing performance evaluation organization of registered houses (registered by the Minister of Land, Infrastructure and Transport) can evaluate housing performance at applicant and issue an evaluation document of housing performance (evaluation document with label, Fig. 3).



Fig. 3 Example of label evaluating performance.

- By making use of a principle that the housing performance displayed in an evaluation document can serve as a contract, the displayed performance can be realized (Fig. 4).

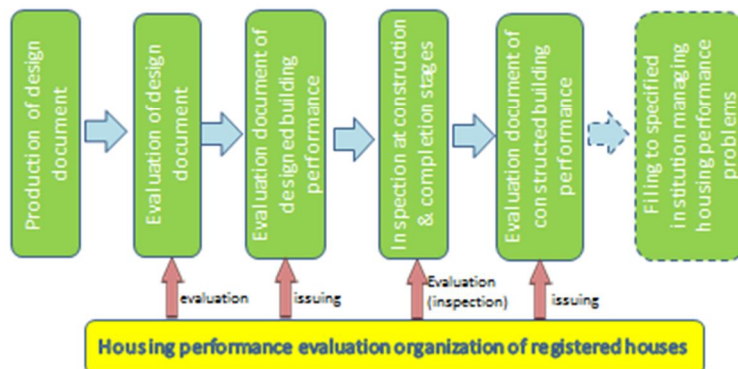


Fig. 4 Flow chart of evaluation process of housing performance (newly built house).

- Establishment of management system dealing with problems regarding housing performance.

#### 3.2 Exception to warranty

The important point of exception to warranty is that, in the contract when buying a newly built house, a warranty period of 10 years is required regarding the basic structural components and a warranty period up to 20 years and including parts other than the basic structural components should be possible.

### 4. Recent research for improving moisture safety in the building process

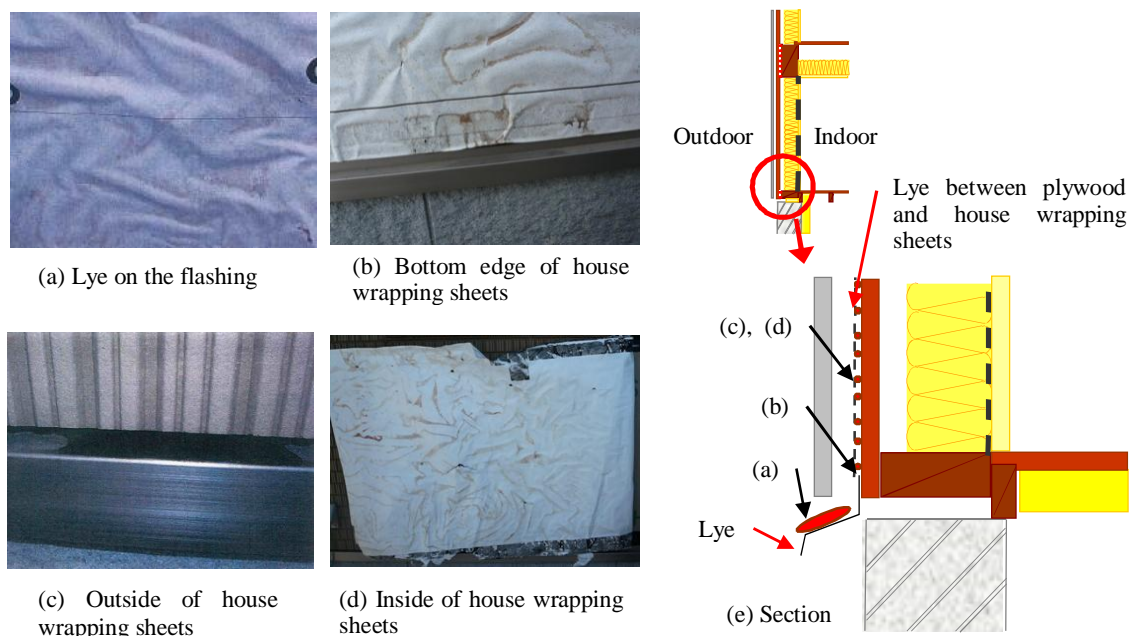
#### 4.1 Moisture damage in vented air space of exterior walls of wooden houses (Umeno, 2011)

**(1) Background** Most of the exterior walls of wooden houses in Japan have a vented air layer between the exterior cladding and the insulation. This vented air layer is designed to dehumidify exterior walls by discharging humidity to the outside and allowing outdoor air to enter, thereby decreasing the risk of condensation on the exterior wall during winter. The source of this moisture is assumed to be the indoor air; that is, the outdoor air is assumed to be drier. However, the outdoor air is often highly humid during the rainy season and may become a source of moisture. The vented air layer also allows rainwater to drain away. Any rainwater penetrating through the exterior cladding is drained away through the vented air layer. However, rain can also enter the vented air space through the air inlets. Water might accumulate in the vented air layer and produce high humidity in the exterior wall. This section describes a case of moisture damage where lye appeared on the outer surface of a plywood wall.

**(2) Moisture damage to an exterior wall with a vented air layer: Lye from plywood**

Figure 5 shows a case of moisture damage in the vented air layer of an exterior wall in a 4-year-old wooden residential building. Reddish-brown water was observed flowing between the plywood and the house wrapping sheets. This reddish-brown water was determined to be lye from the plywood. Lye generation was mainly observed at the contact points between the plywood and the house wrapping sheets. Furthermore, staples in the plywood had rusted.

There was no evidence of condensation on the inner surface of the plywood, on the insulation, or on the posts and beams. Lye typically appeared in houses with a thin vented air layer, and was mainly found in east-facing walls. The lye was usually observed during the rainy season or in summer. Because the lye was distributed all over the surface of the plywood, condensation likely occurred on the outer surface of the plywood. The moisture source for the condensation could be either rainwater or outdoor air (or both). Because humidity increases readily in spaces with a small volume and low ventilation rate, the lye tends to appear in walls with a thin vented air layer.



*Fig. 5 Lye generation in a vented air layer.*

### (3) Experiments simulating lye generation

Experiments designed to simulate lye generation were performed in climate chambers. An external test wall consisting of a wooden post-and-beam framework covered in plywood and house wrapping sheets was constructed between two climate chambers. The temperature and humidity of climate chamber 1 were controlled to simulate the vented air layer, and chamber 2 was used to simulate the external surface of the insulation layer of the external wall. Experiments were then performed using three temperature and humidity combinations based on temperature and humidity measurements taken during the rainy season in Japan (Table 1). Each experiment was performed for one week. The condition of the test wall was observed visually.

In case 1 and case 2, neither condensation nor lye generation were observed on the plywood surface. In case 3, under the severest test conditions, a small amount of condensation was observed on the plywood surface immediately after the start of the experiment. The amount of condensation increased over time. After 24 hours, reddish-brown water was observed on the flashing. Figure 6 shows the change in the appearance of the test wall during the experiment in case 3. After one week, mold was observed on the plywood surface and rust was observed on the staples of the house wrapping sheets (Fig. 6 (b) and (c)).

**(4) Analysis of condensation in the vented air layer** The hygrothermal characteristics of the vented air layer were evaluated using numerical analysis, and the possible causes of condensation in the vented air layer were investigated. Outdoor airflow into the vented air layer could not be the cause of condensation leading to lye generation on the plywood. Instead, rain penetration through the exterior cladding was a more likely cause of lye generation.

*Table 1 Experimental conditions.*

	Case 1	Case 2	Case 3
Vented air layer	30 °C, 70% RH	35 °C, 70% RH	40 °C, 70% RH
Insulation layer	20 °C, 55% RH	24 °C, 55% RH	26 °C, 55% RH
External surface of plywood	26 °C	30 °C	34 °C



(a) Lye on the flashing



(b) Mold on plywood



(c) Rust on a staple

*Fig. 6 Change in appearance of the test wall in case 3.*

## 4.2 Hygrothermal conditions in attic spaces of wooden houses with eaves ventilation (Matsuoka, 2015)

**(1) Introduction** In Japan, roofs are generally constructed with plywood sheathing boards as an anti-earthquake measure. Consequently, the moisture in the attic space cannot be easily discharged outside and condensation often occurs on the sheathing roof board surface in winter in the attics of wooden houses whose ceilings are insulated. The governmental organization Japan Housing Finance Agency (“JHFA”), which finances end users for purchasing a house, plays an important role in improving the quality of Japanese houses. A general specification published by



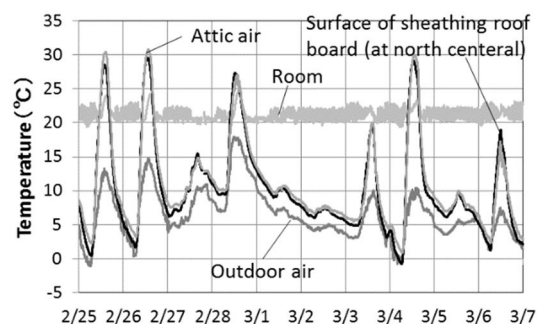
the organization provides a standard area for ventilation openings in attic spaces (JHFA). However, a rationale for this standard cannot be found in the literature in Japan. In response to new standards for energy saving, the insulation and air tightness performance of recent Japanese houses has been improved. The installation of a high vapor barrier in the ceiling, for example, decreased the moisture flow from the room to the attic space compared to houses built before the Agency Standard was implemented. From these viewpoints, the formulation of a guideline for an attic's necessary ventilation opening area that depends on the local climate is needed.

**(2) Experiments** A mock-up, one-story test house (3.64 m × 3.64 m floor area and a 2.54 m ceiling height) with eaves ventilation (Photo 1) was built in a suburb of Tokyo. The ceiling comprised two-layered glass wool insulation with a density of 10 kg/m<sup>3</sup>; the insulation was 100 mm thick and was packed in polyethylene bags. On the indoor-facing side of this insulation material, a polyethylene film was attached to prevent the fibers from being scattered and to prevent condensation. The measurements were performed from February 2014 to April, 2014. The room temperature was controlled to approximately 21 °C using an air conditioner and humidity was controlled to approximately 50% to 60% using a humidifier.

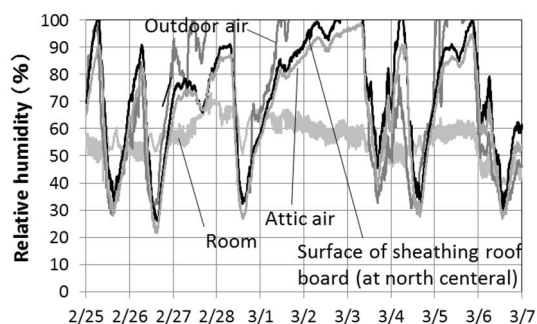
**Hygrothermal fluctuations in the attic space.** The measured results are shown in Figs. 7–9. The relative humidity of the attic space tended to be high during early mornings. Condensation was likely to occur on the sheathing roof board every day (Fig. 8). The absolute humidity increased until early afternoon, decreased during the evening, and was almost constant during the night (Fig. 9). The absolute humidity was sometimes lower in the attic space than that in the outdoors during the night (encircled in Fig. 9).



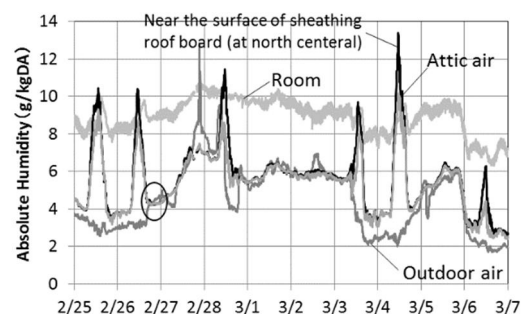
*Photo 1—Eaves vent of the experimental house (north side).*



*Fig. 7 Temperature in the test attic space.*



*Fig. 8 RH in the test attic space.*



*Fig. 9 Absolute humidity in the test attic space.*

### **(3) Airflow rates through the building elements enclosing the attic space**

Figure 10 shows the estimated daily average of the incoming/outgoing flow rates through the vented eave cavities, and Fig. 11 shows the flow rate through the vented wall cavity. The



average ventilation rate of the attic was 10.5 times/h through the eaves ventilation opening and 1.6 times/h through the vented wall cavity. The airflow rate through the ventilation opening (north) was substantial mainly because of the location of the experimental house and the climatic conditions. The amount of upward flow through the vented wall cavity was approximately the same for the north and south walls and most of it flowed into the attic space. In the case of the flow rate through the vented cavity in the southern wall, the ratio among the upward airflow into the attic space, upward airflow into the eaves ventilation opening, and downward flow was approximately 5:1:4. Given that 20% of the upward airflow through the vented wall did not contribute to ventilating the attic, the eave space should be incorporated into the simulation model to investigate the proper size of the attic ventilation opening.

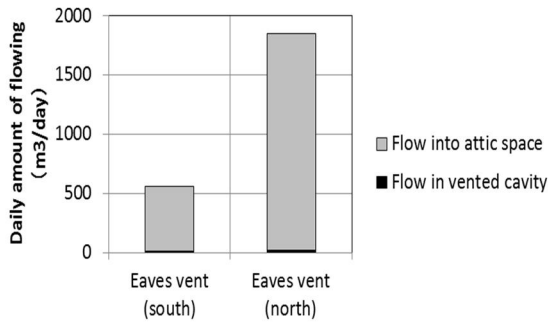


Fig. 10 Flow rate through the eaves vents.

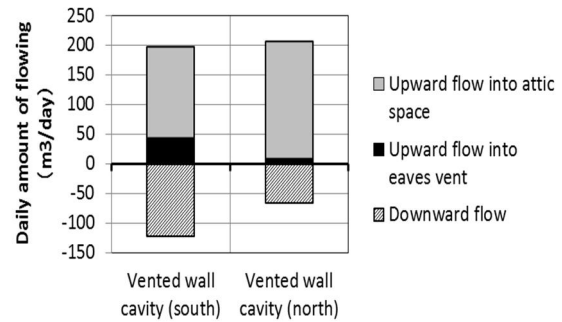


Fig. 11 Flow rate through the vented wall cavity.

**(4) Hygrothermal analysis of the attic space** The attic used in the simulation is shown in Fig. 12. The simultaneous transfer of the heat and moisture in the hygroscopic regime was analyzed (Matsumoto, 1971). The calculated relative humidity of the sheathing board's (north) surface was in good agreement with those measured (Fig. 12). The calculated attic temperature, attic absolute humidity, absolute humidity of the eave space, and other temperatures and humidity (omitted) were also in good agreement with the measured values.

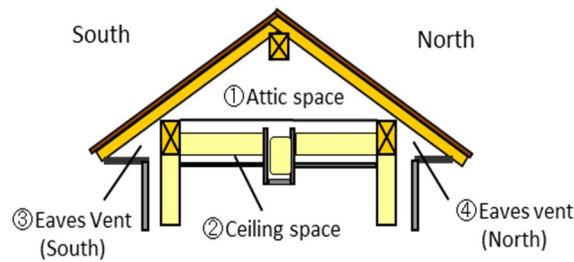


Fig. 12 Calculation model.

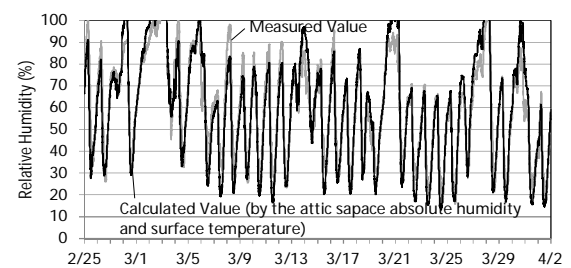


Fig. 13 RH at the sheathing roof board surface (north, inner side).

**(6) Dehumidification of the attic space by building elements (daily average).** The daily average of the dehumidification in the attic space by the building elements during the experimental period is shown in Fig. 14. The amount of dehumidification through the ventilation opening (north) was substantial. The amount of moisture desorption and absorption by the wooden materials in the attic was approximately the same, and the humidification due to advection vapor flow

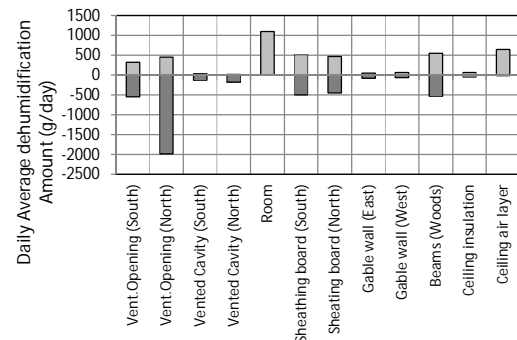


Fig. 14 Daily average dehumidification amount.

the ceiling air layer was approximately the same as that by each of the north and south sheathing boards. These results indicate that the existence of the wooden materials in the attic space, air tightness of the ceiling surface, and method of constructing the ceiling insulation are essential when examining the moisture balance of an attic space.

#### 4.5 Prevention of condensation in the spandrel of glass curtain walls (Gondo 2011)

**(1) Introduction** In recent years, glass curtain walls have been increasingly used for the entire walls of office buildings in Japan because of their aesthetic appeal. At the same time, demand has been strong for maintaining suitable humidity in buildings in winter from the standpoint of enhancing the comfort and health of people indoors. Under this humidity condition, condensation in spandrels (Fig. 15) of glass curtain walls occurs from time to time. This condensation is considered to occur because of the entry of warm and humid indoor air into the spandrels and/or because of desorption of moisture from the refractory boards (calcium silicate boards) installed to prevent a fire from spreading to the upper and lower floors. Spandrel mock-ups were constructed and experiments were carried out to investigate the influence of various factors such as indoor interstices, outdoor interstices, moisture content, and type of calcium silicate board on condensation.

##### **(2) Experiment on condensation without solar radiation (Experiment I)**

To understand the influence of the indoor temperature and humidity, the interstices around calcium silicate boards, etc., a mock-up glass curtain wall spandrel was installed (Fig. 16) in a climate chamber. The experimental cases are presented in Table 2, with Case 1-1 as the standard case. The calcium silicate board used was a 20-mm-thick tobermorite-base.

With an increase in indoor humidity, the dew point of the cavity increased compared to the standard case, Case 1-1 (Fig. 17). Even when the indoor humidity was increased to 35% and 45%, the dew point inside the cavity did not increase under airtight conditions (Case 1-5). The amount of condensed water on the glass surface and the dew point in the cavity at an indoor RH of 45% are shown in Fig. 18. Insulating the indoor side of the calcium silicate board and providing a hole for ventilation of room air should be avoided.

##### **(3) Experiment on condensation with solar radiation (Experiment II)**

The influence of the liberation of moisture from the calcium silicate board was investigated under solar radiation. Infrared radiation was applied for approximately 7 hours to simulate the temperature rise induced by solar radiation. The results of the experiment with the indoor-side interstices sealed under solar radiation showed that, when interstices are provided at the outdoor side, the cavity is ventilated and the amount of condensed water decreases. The influence of the calcium silicate board type on condensation on the glass surface was observed to be important, and when a calcium silicate board with low moisture content was used or when the board was

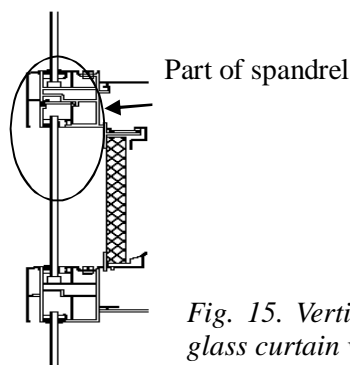


Fig. 15. Vertical section of glass curtain walls.

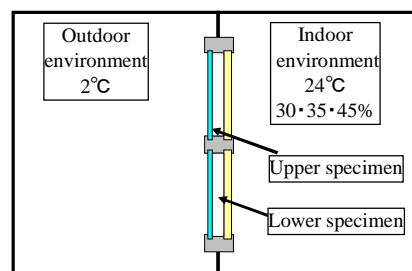


Fig. 16. Experimental equipment in a climate chamber.

Table 2. Experiment cases in Experiment I.

Case	Indoor-side interstices		Outdoor-side interstices		Refractory board moisture content (wt%)	Inside insulation
	Condition	Equivalent opening area [cm <sup>2</sup> ]	Condition	Equivalent opening area [cm <sup>2</sup> ]		
1-1	Standard	55.09	Condensate drain valve at bottom 10 φ × 2	0.06	normal (18.0)	none
1-2					low (6.0)	
1-3					normal (12.8)	urethane 30mm
1-4	Closing vertical interstices	25.81			low (8.2)	none
1-5	Air tight	1.5			normal (16.9)	
1-6	Vent hole	75.58			low (8.8)	

\*Every refractory board was a tobermorite-based calcium silicate board

Fig. 18. The amount of condensed water on the glass surface and the dew point in the cavity at an indoor relative humidity of 45%.

covered with a metallic sheet on the surface, the amount of moisture desorption into the cavity decreased and hardly any condensation occurred. When urethane was sprayed onto the entire interior surface, the extent of moisture desorption was substantial and condensation occurred even when a calcium silicate board with small moisture content was used. A certain time is required for the calcium silicate board to reach equilibrium.

## 5. What challenges is the construction sector facing in Japan?

1. Technology development.
2. Change in lifestyle: concentration of population in urban areas and population aging.
3. Mutual understanding between technology and design: design education.

## 6. References

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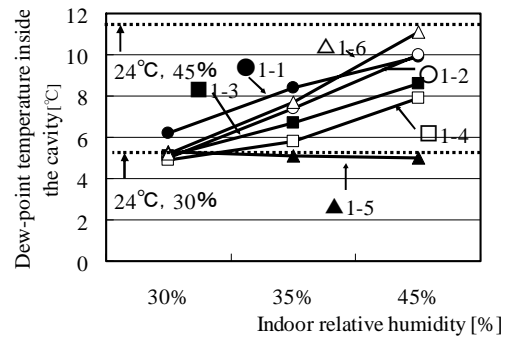
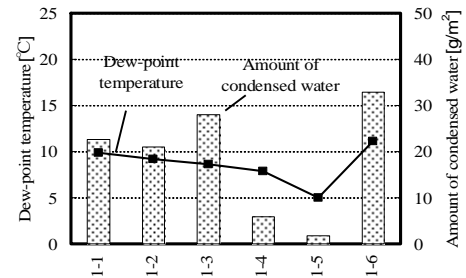


Fig. 17. The dew-point inside the cavity.



# Moisture and building processes in Finland

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## Abstract

Moisture management is crucial to achieving good construction quality in the Nordic countries, for avoiding moisture safety risks and for reducing energy use, which can have environment impacts. Heating and ventilation are important factors in managing site conditions.

A case study has been performed on Finnish construction sites involving observation of the heating methods, weather guards, drying and other circumstances at the sites. The purchased energy and electricity consumption were measured and analysed at two building sites. The energy use in the measured construction sites varied from 18 to 54 kWh/m<sup>3</sup>. Site heating for concrete strengthening and structure drying were the highest energy consumers.

This paper reviews drying and heating practices and some recent development in moisture safety issues in Finland. In the end of the paper, related to topic of reducing energy related to moisture management, this paper also discusses, how more energy efficient heating and drying planning methods could be developed for construction sites.

Keywords: construction site, drying, energy, heating, moisture,

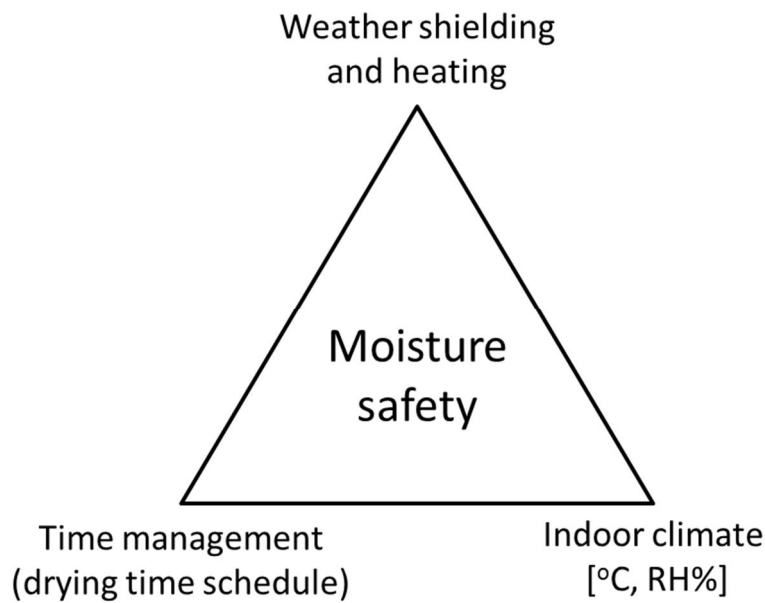
# 1. Introduction

Finland is a Nordic country in the temperate/boreal climate region. The weather conditions significantly vary between seasons in the Nordic countries. For example, the average wintertime duration is 163 days in southern part of Finland. The century-long average for wintertime snowfall is 175 mm in Helsinki and 228 mm in Sodankylä, whereas the rainfall values are 191 mm in Helsinki and 67 mm in Sodankylä. (Irannezhad et al. 2015).

During construction, there are various temperature and relative humidity requirements for the concrete drying time in cold conditions. Unnecessary wetting of concrete and other elements should be avoided because, among other things, it can require additional drying. The energy, hiring, working, transportation and energy distribution system costs must be considered when choosing a drying method. The speed of drying depends on the internal and external humidity, temperature, amount of ventilation and drying materials as well as the related chemical reactions. The larger the temperature and humidity difference between the internal and external climate, the more effectively the ventilation can accelerate the drying processes. The ventilation facilitates drying in the building site most of the year, but ventilation is not as helpful in the summer and early autumn periods, when the outside humidity is high. In summer and autumn, dehumidification equipment is often utilized at Finnish construction sites to speed up the drying processes.

Heating is necessary for enabling construction work during the winter and spring for both technical reasons and productive working conditions. Heating is one of the biggest energy consumers at construction sites during the cold winter climate. Unnecessary energy consumption is both economically and environmentally unsuitable. One aim of energy efficiency management at construction sites is to keep heat inside the envelope while maintaining adequate ventilation. There is remarkable energy and emission savings potential at construction sites. The energy use for construction site moisture management has been inadequately studied to date. In Finland, the energy used for constructing and producing construction materials is estimated as approximately 8% of the total energy use. This energy use accounts for an approximately 4% share of the building material manufacturing; 3% is allocated to ground transportation, and 1% is allocated to building site operations. (Vainio 2012.) According to Teriö & Honkanen (2013) the energy use in Finnish new building construction sites varies approximately from 18 to 54 kWh/m<sup>3</sup>.

The purpose of this paper is to introduce the scope of moisture management at construction sites in cold climate. Moisture management is crucial to achieving good construction quality in the Nordic countries. Heating and ventilation can be used to manage the site conditions. Also, the aim of the paper is to determine i) how much energy is used at construction sites in Finland and what energy sources are utilized ii) what kind of measures have been taken to improve moisture safety in Finnish construction, iii) how moisture and heating management could be further developed also towards more energy efficient directions. These issues are important to consider when the goal is to produce high-quality construction sites environmentally efficiently.



*Figure1. The moisture safety needs an integration of weather shielding, heating, good indoor climate and enough time to dry moisture. The moisture of the concrete is a key issue. It takes time and heating to dry process water away from concrete before coating it. Relationships between heating, indoor climate and drying time are dealt with in this paper.*

## 2. Drying and heating at Finnish construction sites

A case study has been performed on two Finnish construction sites by observing the drying and heating methods, weather guards, and indoor climate circumstances at various sites. The construction sites were from southern part of Finland, where most new buildings are In addition, the energy consumption at six sites was analysed based on accounting information. currently being built. Energy use was measured at two construction sites. At these sites, the energy for electricity, fuel, gas and district heating were measured and the heating, drying and site office energy use were evaluated. At one site, a crane's electricity use was measured. In addition, the energy consumption at six sites was analysed based on accounting information. During the study, interviews and workshops were performed to collect data and improve the knowledge and knowhow of construction personnel. Ground work machines are also considerable energy consumers in construction sites, but these were restricted from the present study.

Both case buildings were six-floor high, multi-storey apartment houses. The area of the first site (case A) was 6467 square meters and building volume was 20900 cubic meters. It had 99 apartments. In addition, there was a parking hall (1600 m<sup>3</sup>). In the other case (case B), the area of the site was 3797 m<sup>2</sup> and volume was 14161 m<sup>3</sup>. There were 51 apartments and there was a parking hall (2300 m<sup>3</sup>). The construction time was 20 months in case A and 17 months in case B.

According to the case study interviews, liquefied gas heating was used at the frame phase for both building sites. The liquefied petroleum gas heaters were light and small relative to the heating power. The gas heaters can be situated only in rooms where the ventilation level is sufficiently

high. Usually, the power of the gas heaters in the building site is 25-150 kW. The gas heating itself produces a considerable amount of water vapour, which increases the need for drying.

Oil heaters are used to heat wide spaces, such as industrial halls, office premises and storage spaces. Usually, oil heating is used at a frame phase when the heating power is forceful. Oil heating produces carbon dioxide and water vapour, but the water by-product level is lower than for gas heating. Also, oil heater containers can be placed outside the envelope. Then, carbon dioxide and water vapour can be directly ventilated outside.

Different methods of electric heating include heater fans, heating carpet, infrared heaters and electric heating cables for concrete. Electric heating is easy to use, and it is especially important for heating small areas. The heating cables for concrete can be used for the footing units, pillars, beams and element joints. The heating cable is an energy-efficient method for strengthening and pouring concrete structures compared to heating wider spaces, but additional work is needed to install the cables in the concrete. The accessibility of the electric network is often too small for electric heating to be applied for all uses. According to interviews, the expertise regarding cable heating is decreasing.

General district heating systems are utilized if they are available. District heating fans are often placed at the late phase of the framework or before beginning indoor work. The intensity of district heating is not always sufficient for heating the entire building. Also, energy prices vary, and district heating is often the cheapest method of energy in Finland; therefore, it is used as early as possible.

Over 2/3 of the energy is used to heat and illuminate buildings and barracks. Drying equipment is also a relevant topic. Cranes and electric tools use notably little energy. The total energy consumption in two Finnish case studies is described in the Table 1. District heating consumes approximately 55% of the energy, heating by gas 14%, lighting and other equipment 21%, drying 6%, site office heating and rest room electricity 3% and cranes 1%.

Table 1. Energy consumption at two building site cases, energy sources and distribution. (Teriö & Honkanen 2013)

	Case A	Case B	
<b>Total energy consumption</b>	1087	742	MWh
Energy consumption per volume	52	52	kWh/m <sup>3</sup>
<b>Total heating energy (direct)</b>	35.9	39.5	kWh/m <sup>3</sup>
-District heating	28.6	21.8	kWh/m <sup>3</sup>
-Heating oil		5.7	kWh/m <sup>3</sup>
-Gas	7.3	12	kWh/m <sup>3</sup>
<b>Total electricity</b>	16.1	12.5	kWh/m <sup>3</sup>
-Lighting, embedded-wire heating, crane (1%), gas evaporator, other equipment	11.6	Not measured	kWh/m <sup>3</sup>
-Drying machines	3.1	Not used	kWh/m <sup>3</sup>
-Site office and rest rooms	1.6	Not measured	kWh/m <sup>3</sup>

Table 2. Typical climate circumstances in the case study area.

Weather statistics			
Month	Average temperature	Average RH %	Rain [mm]
I	-6.7	89	45
II	-7	87	44
III	-2.8	82	41
IV	3	71	36
V	9.5	62	31
VI	14.4	65	33
VII	16.5	69	35
VIII	14.6	76	38
IX	9.4	82	41
X	4.7	87	44
XI	-1	90	45
XII	-4.6	91	46

In a framework phase, liquefied petroleum gas was typically used for heating, but oil and district heating were also used. An indoor phase mostly used district heating. In case B, oil heating was used in the parking hall site of the indoor phase. Approximately 40%-50% of the total energy use was used during the frame work and 50%-60% during the indoor phase.



Approximately 70% of the electric energy is used for lighting, fans, drying equipment and electric tools. In the first case, the indoor phase used 63 MWh of electric energy, which corresponds to 22 kWh/m<sup>2</sup>/year. The second case used 141.5 MWh of electric energy, which corresponds to 29 kWh/m<sup>2</sup>/year.

The total energy use at a site office was 7680 kWh/year. The site offices are placed side-by-side and one on top of the other. Approximately half of the energy was used for space heating and the other half for office equipment. In the summer, most of the energy was used for the equipment because heating was not needed. The electricity use of barracks is approximately 30% of the total electric energy use in case studies.

### **3. Measures taken for improving moisture safety of building processes in Finland**

Moisture damages, and mold and health problems related to them, are serious and expensive problems in Finnish building sector (Audit Committee of Parliament of Finland, 2012). In the year 2013 the Parliament of Finland required the government to take measures for mold and moisture problems in the building sector, including instructions of construction processes and guidance issues (Parliament of Finland, 2013). Thereafter there have been several projects for developing new methods and best practices, for example with the funding of Finland's Ministry of the Environment and the Confederation of Finnish Construction Industries RT, some web pages have been drawn up which presents instructions from the separate points of view (see [www.hometalkoot.fi](http://www.hometalkoot.fi) and [www.kosteudenhallinta.fi](http://www.kosteudenhallinta.fi) )

In addition to giving instructions, there has been also some legality development. Ministry of Social Affairs and Health (2003) had given an Instruction for housing healthy in 2003 (in Finnish: Asumisterveysohje). However, instruction level regulation was not seen as enough anymore, and in 2015 a new Act was given by Ministry of Social Affairs and Health, which has more legal force than voluntary type instructions. In this Act there are several commands related to what kind of circumstances have to be in houses. This Act also sets competence requirements for qualified external experts in the case of moisture and mold damage and indoor air problems.

Moisture management practices have been also developed by the building inspection authorities. Building inspection authorities in Oulu have developed so called DryChain10 (In Finnish: Kuivaketju10) procedure, which strive to prevent the moisture problems by recognizing the most typical risks (Mäkikyrö 2015). The procedure has three basic ideas: 1) measures will be focused on ten most significant moisture risks, that cause moisture problems in the buildings , 2) chosen risks are prevented systematically in all construction phases (purchasing, design, construction period, commissioning and maintenance), and 3) results are measured, verified, documented and the further tasks will be appointed. According to developers of DryChain10 the most common moisture problems in Finland are:

1. Moisture from the building's surroundings damages the foundation and the base floor structures.
2. Rain water penetrates into the exterior walls.
3. Water penetrates through leaks in the roof structures and gets all the way to insulation and interior boarding.
4. Moist concrete structures are coated too early in the drying process which causes deterioration of the covering materials.
5. Moisture migrates through the air barrier layer's leakages into exterior wall and roof structures and then condensates into water.
6. Incorrectly designed and/or adjusted ventilation doesn't remove moisture from the building but forces it to migrate into structures.
7. Leakages in the piping cause massive water damages.
8. Badly executed sanitary and bathroom spaces damage the surrounding structures when moisture gets through the surfaces.
9. Materials and structures getting wet damages the building.
10. Neglected maintenance and care cause the building to slowly but surely deteriorate. ([www.kuivaketju10.fi](http://www.kuivaketju10.fi).)

The ten most significant risks are prevented by 20/80 –principle. By concentrating on 20 % of the issues causing problems and getting most of them under control, is striven to achieve about 80 % of the problems in the end.

#### **4. Proposal for developing planning drying and heating management in construction sites**

There are several project management tools for planning schedules by working performance, but nevertheless, drying times can be difficult to integrate into schedule planning. Conversations with foremen in case projects sparked the idea of developing a new calculation model that could facilitate planning for heating and drying.

The scheduling of drying process of concrete is especially is sometimes especially challenging to forecast, because drying process of concrete include many chemical processes, because there are so many things that can affect the drying process both in conditions and materials utilized, and because the process itself is so complex.

However, a simple Excel based model was developed for the drying management purposes in such situations when other issues than the air's humidity are not limiting factors in drying process. With the model the user can tentatively determine how to plan heating and drying conditions as well as the schedule for drying at a construction site. In addition to using the model, the measurements of the concrete moisture remain essential before surfaces are covered.

Inputs to the model include the building features, such the project size [ $\text{Vm}^3$ ] and heating time schedule. Also, the target circumstances of the indoor climate, such as the temperature and relative humidity, need to be defined. The energy price could also be entered into the model [cnt/kWh].

The model proposes the water level (seven litres per building volume), but the user can change the value. The monthly statistics for the climate (the temperature, humidity, and rain) are entered into the model for several locations. The user can also change the climate values. The ventilation factor [1/h] varies substantially during the seasons. The level is low in the winter and high in the summer. When testing the model, these levels were calibrated to the seasons so that the total energy use nearly matches true consumption. In real life, it is unnecessary to know the ventilation factor. However, the current temperature and relative humidity of the site's indoor climate are essential. If the values are insufficient, the ventilation should be increased or decreased. An adequate temperature is approximately 21 degrees and adequate relative humidity is 50% or lower.

The model calculates the time required to transfer the moisture outside. In practice, the time is usually decided earlier so that the user can arrange for proper ventilation (assess the ventilation factor), achieve more efficient drying methods and observe the site circumstances. In the very early stage of the project, it is possible to define the drying time. Then, the user can decide the appropriate drying schedule and methods.

*Table 3. The model calculates indicative information for the project manager, such as the time schedule for dehumidification, approximate maximum heating capacity (kW) for planning equipment and total heating energy for cost planning.*

Outputs														
Months	I	II	III	IV	V	VI	VII	VIII	IX	X	XI	XII	Total	
Ventilation factor (1/h)	0,5	0,5	0,6	0,8	1,2	1,2	1,2	1,2	1,3	0,9	0,7	0,6		
Heating capacity, Ventilation (kW):	48	48	49	50	48	27	19	26	52	51	53	53		
Heating capacity, Envelope conduction (kW):	23	23	20	15	9	5	4	5	10	13	18	21		
Envelope and ventilation, total (kW):	70	71	69	64	57	33	22	32	61	64	71	74		
Envelope and ventilation energy consumption (MWh)	0	48	51	46	42	24	16	24	44	48	0	0	343	
Heating of framework phase (MWh)	50	0	0	0	0	0	0	0	0	0	10	30	90	
Solar energy (MWh)		1	2	4	5	5	5	4	3	1	0		29	
Total MWh													404	
Total €													44430	
Approximate maximum heating capacity (kW)	187	190	187	184	173	84	35	57	154	170	192	199		

There are numerous challenges when planning drying, such as with the rain per construction volume, the moisture level, weather, building shape, conduction through wet isolation materials, and more. Anyhow the total moisture is approximately 5-10 litres/building volume.

Optimization of heating and drying is a complicated issue. There is an obvious need for simple tools to plan shielding, heating, ventilation and drying. In discussions at sites, many site managers become aware of the preconditioning circumstances for improving the quality and time management and cost of drying.

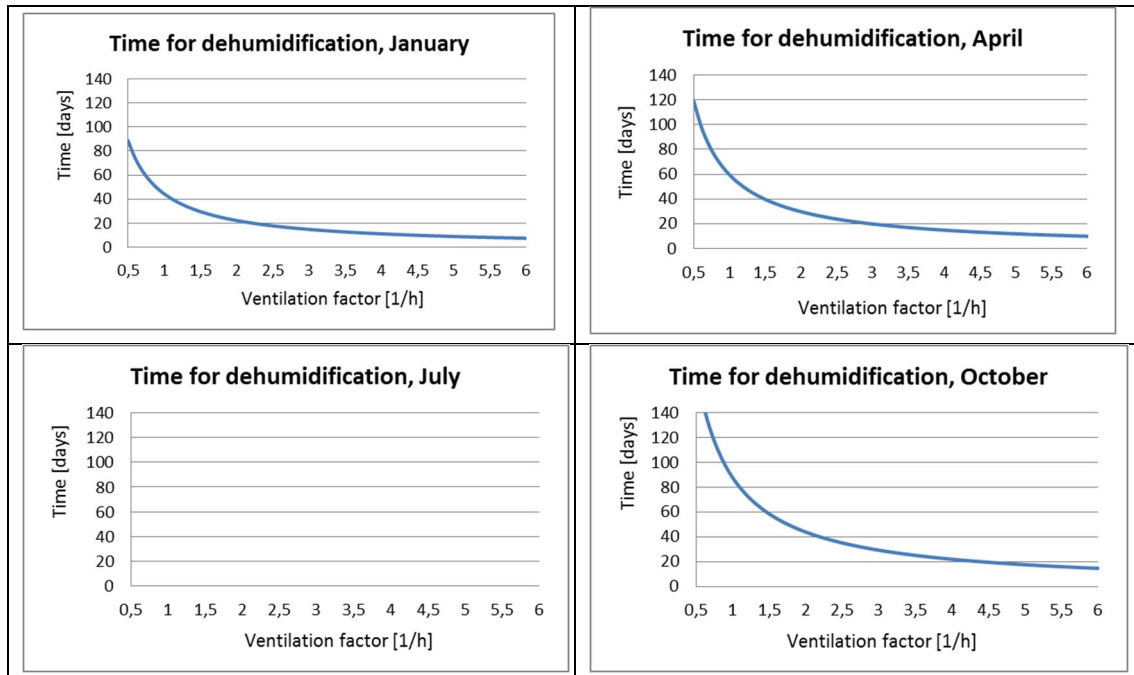


Figure 3. The drying by ventilation is effective in winter and early spring, In July, it can be impossible to dry concrete just by ventilation. At cold season the ventilation factors between 1-3 are usually suitable and energy efficient.

## 5. Discussion

The attitude of foremen is crucial towards achieving moisture safety and energy savings. Knowledge and awareness of moisture behaviour and energy issues are important contributors to energy saving. For example, before starting heating, weather shielding should be adequate. Unfortunately, in practice, there is often insufficient shielding.

When the results of energy use measures of construction site was presented at supervisor training, there was substantial confusion about the amount of energy costs related to heating. Many supervisors were surprised about the extent of heating costs.

There is a substantial need for energy and moisture management training at construction sites. Some sites handle these issues very well, but too many sites either misspend energy or leave concrete wet for too long. When using heating in the coldest seasons, it is important to cover the window and door openings and seal other locations that are not airtight.

There are many areas for further studies. Simple methods for planning site heating and structural drying should be constructed. For example, the heating, drying and schedule optimization are important research areas. Quantitative research on concrete drying in different relative humidity and temperature conditions would be useful. Also, the economics related to the topics presented here should be evaluated in more detail.

## 6. Conclusions

Different measures have been taken in Finland for improving moisture safety of living spaces and construction processes. Improving moisture safety is issue where there are several stakeholders, like legislators, authorities, developers, designers, constructors and users. Several kind of check lists, like in DryChain10, can help in focusing on the most important risk factors, and so intervene especially in the case of most typical moisture risks in the building sites.

Site heating is a significant consumer of energy in cold climates. Heating is needed for concrete hydration and drying and workable working conditions. When the aim is to save energy in the construction sites, heat should be kept inside the envelope while still allowing for adequate ventilation. To boost ventilation, dehumidifiers and fans should be used in certain conditions, especially in the summer and autumn. Unnecessary additional drying should be minimized by sealing interiors from the rain and snow.

The primary energy consumption is related to strengthening the concrete structures and drying them. Energy saving and rapid drying can be conflicting goals, and heating and drying are difficult to plan. There is an obvious need for site education and guidelines. Dehumidifiers and fans should be used in certain conditions, especially in the summer and autumn. Unnecessary drying should be minimized by sealing interiors from the rain and snow.

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